

Arctic Cisco

Blank Page

Chapter 3 Arctic Cisco

Results

Relative Abundance and Distribution: Arctic cisco ≤ 200 mm FL

The following discussions of relative abundance and distribution of Arctic cisco result from two approaches to analyzing the spatial and temporal variation in daily catch rates (fish/d). The first analysis employed a two-way ANOVA which addresses the overall relative contribution of years and sampling areas as sources of variation in CPUE over the 4-year study period. The second set of analyses addresses the spatial and intraseasonal variation observed in daily catch rates of small Arctic cisco within each sampling year.

Two-way ANOVA.— Results of the two-way analysis of variance on daily catch rates of small Arctic cisco (≤ 200 mm FL) and Tukey pairwise comparisons are presented in Table 3.1. Year and sampling area effects, plus the interaction term, were highly significant ($P < 0.0001$). The means comparisons for the year \times area interactions and the main-effect sum of squares (SS) in the ANOVA table indicate that year-to-year variation in CPUE of small Arctic cisco was much greater than was the spatial variation among the sampling areas over that period. Pairwise comparisons of interaction levels indicated that 1990 daily catch rates were generally higher than those of 1989 and 1991, regardless of sampling area. Although an interpretation of main effect means is inappropriate in the face of a significant interaction effect, the high apportionment of the total model SS to the "year" main effect (1118.34 vs. 132.81) corroborates the above conclusion. Reversing the order in which the main effects entered the computer algorithm did not alter the results.

Daily CPUE for each station and progressive mean wind vectors are plotted against time (Figure 3.1). The CPUE plots present a clear visual depiction of the increased daily catch rates in 1990 when compared to 1989 and 1991. The summer of 1990 was characterized by mostly easterly winds, whereas winds were mostly variable during the 1989 and 1991 sampling seasons (Figure 3.1).

Spatial differences.— Within-year comparisons of daily catch rates showed differences in the relative abundance of small Arctic cisco among net stations (Table 3.2; Figure 3.2). In 1989 net station SC04 had significantly higher daily catch rates than all other net stations excluding net station SC01. Net stations within a sampling area did not differ. Daily catch rates in 1990 at net station BL02 were higher than those at net stations SC01, SC04, KL10, and BL04. Net stations SC01, SC04, KL10, and BL04 had the lowest daily catch rates observed. No differences in daily catch rates were detected between net stations within a sampling area for Simpson Cove, Kaktovik and Jago lagoons. During 1991 some of the highest daily catch rates for small Arctic cisco occurred at net stations BL02 and BL04. The lowest daily catch rates were observed at net stations SC01, KL05, KL10, and JL12.

TABLE 3.1.— Two factor analysis of variance on log-transformed daily catch rates ($\ln(\text{CPUE}+1)$) and Tukey means comparisons for Arctic cisco ≤ 200 mm FL from coastal waters of the Arctic Refuge. Effects followed by the same letter are not significantly different ($P > 0.05$). Mean_g = geometric mean.

Source	df	Sum of squares	Mean square	F-value	P-value
Model					
Year	2	1118.34	559.17	231.70	0.0001
Area	3	132.81	44.27	18.34	0.0001
Year×Area	5	183.91	36.78	15.24	0.0001
Error	1006	2428.20	2.41		
Total	1016	3863.26			

Year	Mean _g	Tukey grouping
1990	3.49	A
1989	1.44	B
1991	1.20	B

Area	Mean _g	Tukey grouping
Beaufort	2.83	A
Jago	2.31	B
Simpson	2.01	B
Kaktovik	1.50	C

Year×Area	Mean _g	Tukey grouping
1990-Jago	4.41	A
1990-Beaufort	3.69	A B
1990-Kaktovik	3.31	B C
1990-Simpson	2.64	C D
1989-Simpson	2.02	D E
1991-Beaufort	1.87	E F
1989-Jago	1.51	E F G
1991-Simpson	1.15	F G H
1991-Jago	1.06	G H
1989-Kaktovik	0.75	H
1991-Kaktovik	0.56	H

1002 COASTAL FISHERIES STUDY, FINAL REPORT, 1988-91

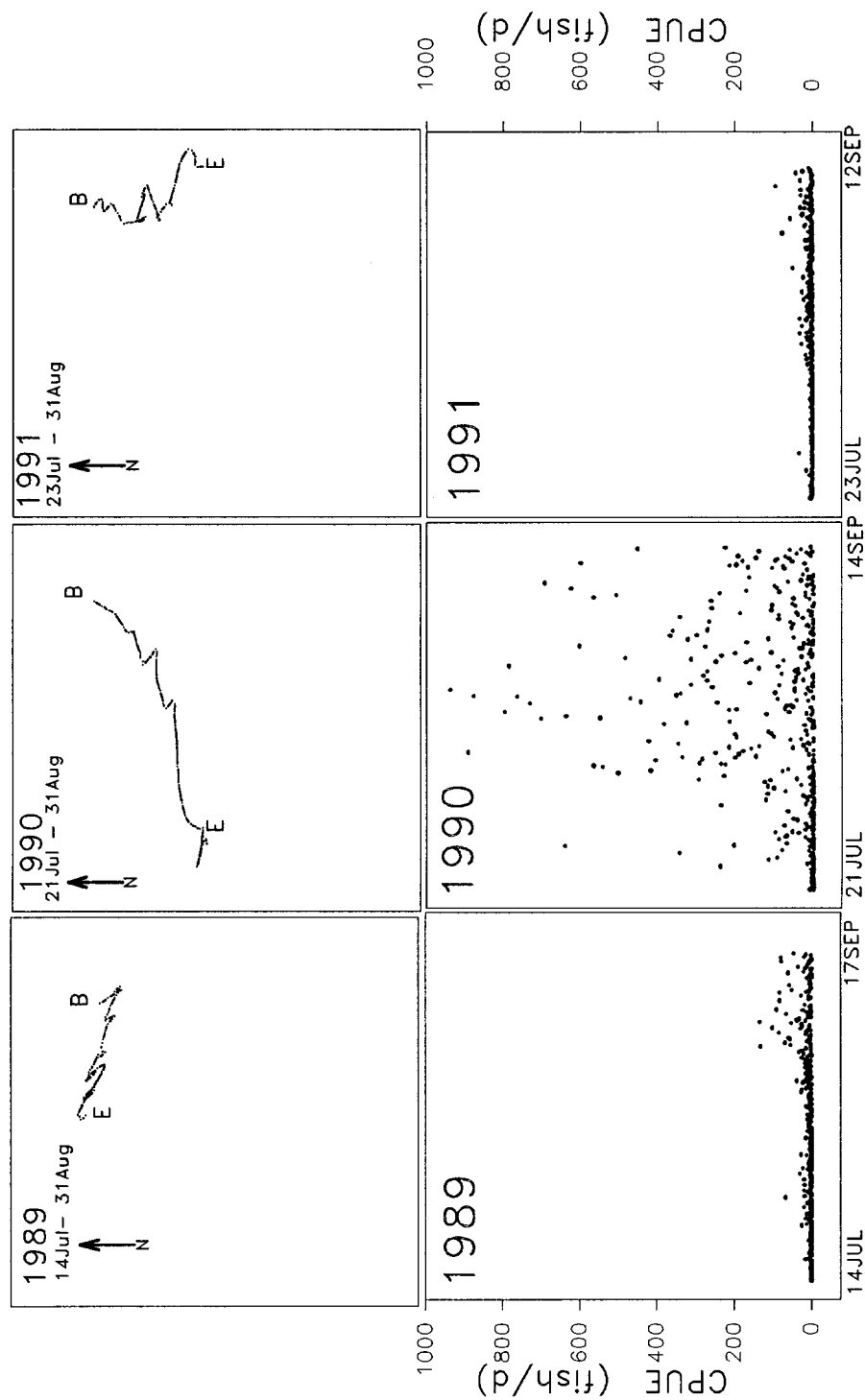


FIGURE 3.1.1.— Time series of average daily July and August wind vectors on the Arctic Refuge coast (top) and CPUE for Arctic cisco ≤ 200 mm FL for all net stations (bottom), 1989-91. Progressive wind vectors depict effective daily direction of wind and relative vector magnitudes (B = begin series; E = end series).

TABLE 3.2.— Comparison of daily CPUE (fish/d) observations among net stations for Arctic cisco ≤ 200 mm FL in Arctic Refuge coastal waters, 1989-91. Within each year those net stations with the same letter are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons).

Station	Within year Scheffé groupings		
	1989	1990	1991
SC01	A, B	D, E	A, B, C
SC04	A	B, C, D, E	A, B
KL05	D	A, B, C, D	C
KL10	C, D	C, D, E	C
JL12	B, C	A, B, C	B, C
JL14	B, C, D	A, B	A, B
BL02		A	A
BL04		E	A

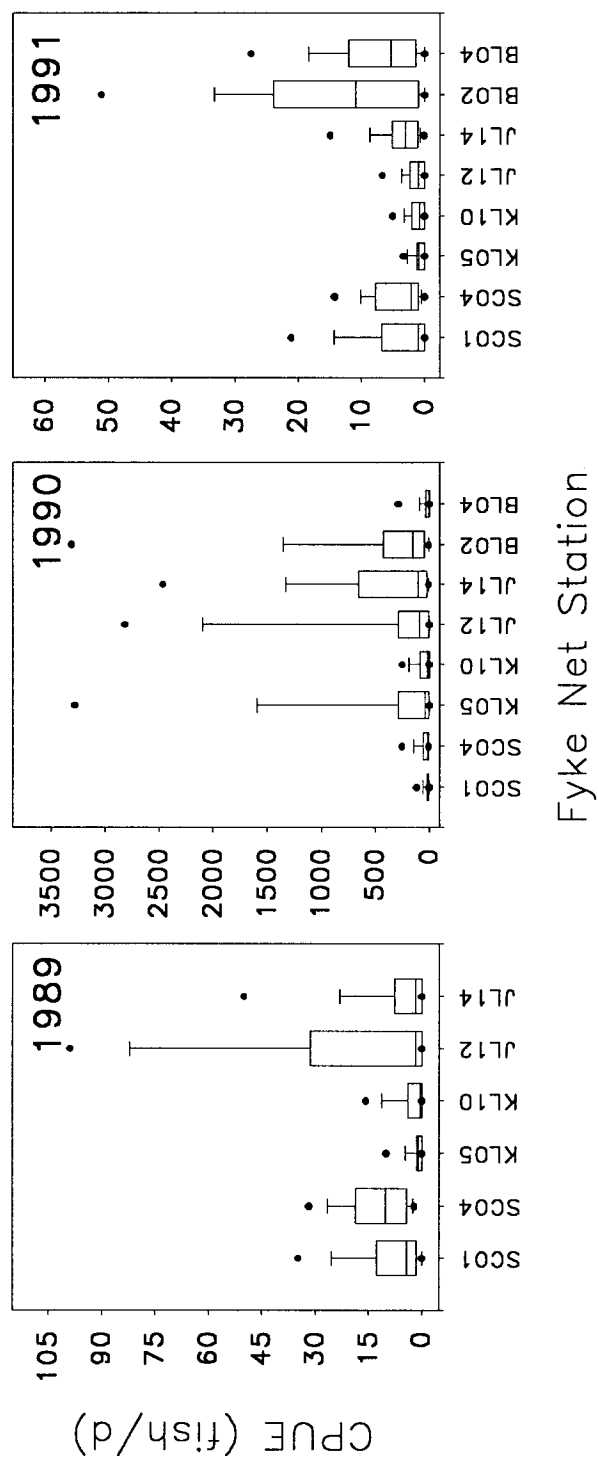


FIGURE 3.2.- Boxplots comparing daily CPUE (fish/d) observations among net stations for Arctic cisco ≤ 200 mm FL in Arctic Refuge coastal waters, 1989-91.

Differences in the daily catch rates of small Arctic cisco among sampling areas were noted (Table 3.3; Figure 3.3). During 1989 daily catch rates decreased moving eastward from Simpson Cove to Jago Lagoon. In 1990 daily catch rates increased moving in an easterly direction from Simpson Cove to Beaufort Lagoon. Small Arctic cisco daily catch rates in 1991 were highest in Beaufort Lagoon, followed by Simpson Cove and Jago Lagoon, and lowest in Kaktovik Lagoon.

Temporal differences.— Daily catch rates of small Arctic cisco at net station SC01 in 1989 and 1991 peaked between August 15 and August 31, and declined after September 1 (Table 3.4; Figures 3.4 and 3.6). In 1990 daily catch rates were stable at net station SC01 during the sampling season (Table 3.4; Figure 3.5). With the exception of July 1990 when they were lower, daily catch rates at net station SC04 were stable during the sampling seasons of 1989, 1990, and 1991. Small Arctic cisco daily catch rates in Simpson Cove were low at the beginning of sampling in July 1989-1991. Increases in daily catch rates were observed in August of the 1989-1991 sampling seasons.

At net stations KL05, KL10, and in the Kaktovik Lagoon sampling area daily catch rates of small Arctic cisco increased during the latter half of the 1989 sampling season (Table 3.5; Figure 3.7). During 1990 daily catch rates at net stations KL05, KL10, and in the Kaktovik Lagoon sampling area were stable during 3 out of 4 time periods (Table 3.5; Figure 3.8). Daily catch rates of small Arctic cisco during the 1991 sampling season were stable at all Kaktovik Lagoon locations (Table 3.5; Figure 3.9).

During the latter half of the 1989 sampling season daily catch rates of small Arctic cisco increased at net stations JL12, JL14, and in the Jago Lagoon sampling area (Table 3.6; Figure 3.10). In 1990 daily catch rates at net stations JL12, JL14, and in Jago Lagoon started low in July, peaked during August and declined after September 1 (Table 3.6; Figure 3.11). Daily catch rates of small Arctic cisco during the 1991 sampling season were stable at all Jago Lagoon locations (Table 3.6; Figure 3.12).

In 1990 daily catch rates of small Arctic cisco were stable during at least 3 out of 4 time periods at net stations BL02 and BL04 and in the Beaufort Lagoon sampling area (Table 3.7; Figure 3.13). During the 1991 sampling season daily catch rates increased at all Beaufort Lagoon locations (Table 3.7; Figure 3.14). At net stations SC01 and SC04 among-year comparisons indicate that daily catch rates were lowest in 1991 and did not differ between 1990 and 1989 (Table 3.8; Figure 3.15). For net stations KL05, KL10, JL12, JL14 and BL02, 1990 daily catch rates were the highest of the years analyzed (Table 3.8; Figures 3.16-3.18). Daily catch rates did not differ between years at net station BL04. In all sampling areas 1990 daily catch rates were the highest among the years analyzed. Daily catch rates in 1991 were the lowest observed in Simpson Cove and Beaufort Lagoon. No differences were observed between 1989 and 1991 daily catch rates in Kaktovik and Jago lagoons.

Within time period, among-year comparisons showed that July 1991 daily catch rates were the lowest among the years at net station SC01 (Table 3.9; Figure

TABLE 3.3.— Comparison of daily CPUE (fish/d) observations among sampling areas for Arctic cisco ≤ 200 mm FL in Arctic Refuge coastal waters, 1989-91. Within each year those sampling areas with the same letter are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons).

Sampling area	Within year Scheffé groupings		
	1989	1990	1991
Simpson Cove	A	C	B
Kaktovik Lagoon	C	B, C	C
Jago Lagoon	B	A	B
Beaufort Lagoon		A, B	A

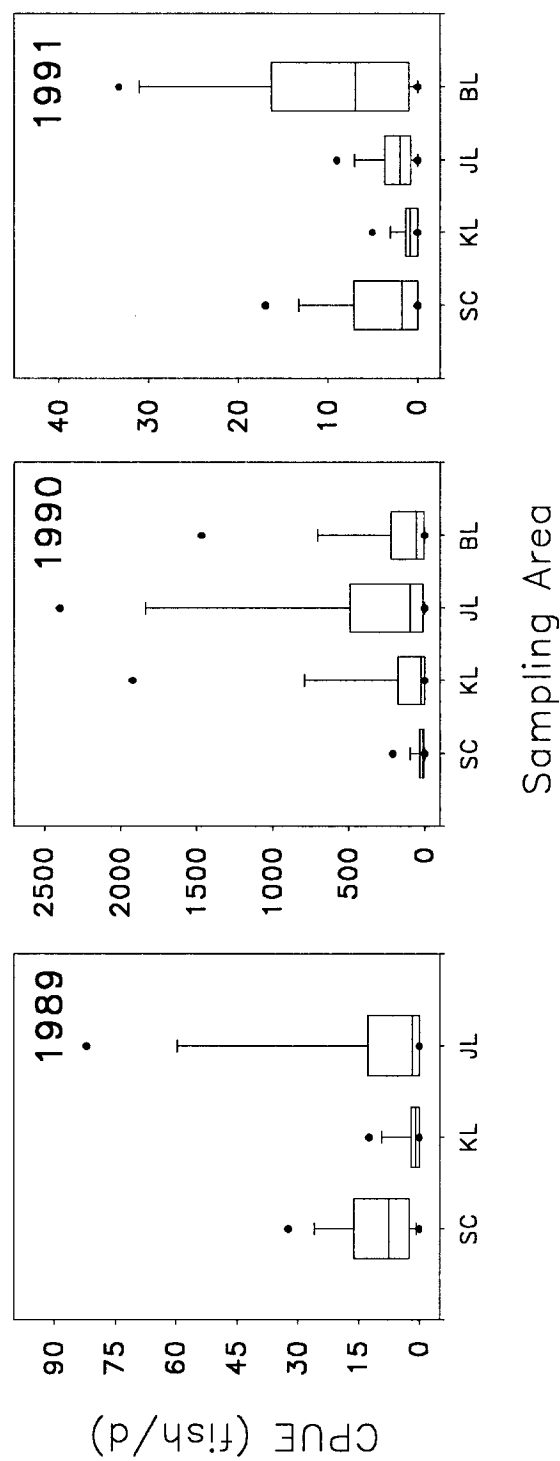


FIGURE 3.3.- Boxplots comparing daily CPUE (fish/d) observations among sampling areas for Arctic cisco ≤ 200 mm FL in Arctic Refuge coastal waters, 1989-91.

TABLE 3.4.- Comparison of daily CPUE (fish/d) observations among time periods for Arctic cisco ≤ 200 mm FL in Simpson Cove, 1989-91. For each net station/sampling area those time periods with the same letter, within each year, are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons). Time period 1 corresponds to the period from the first sampling day to July 31. Time period 2 corresponds to the period from August 1 to August 14. Time period 3 corresponds to the period from August 15 to August 31. Time period 4 corresponds to the period from September 1 to the last sampling day. Locations with dashed lines were not fished during that time period.

Time Period	Within year Scheffé groupings		
	1989	1990	1991
Net Station - SC01			
1	B	A	C
2	B	A	C
3	A	A	A
4	B	A	B
Net Station - SC04			
1	A	B	A
2	A	A	A
3	A	A	A
4	A	A	--
Simpson Cove			
1	B	B	C
2	A, B	A	B, C
3	A	A	A
4	A, B	A	B

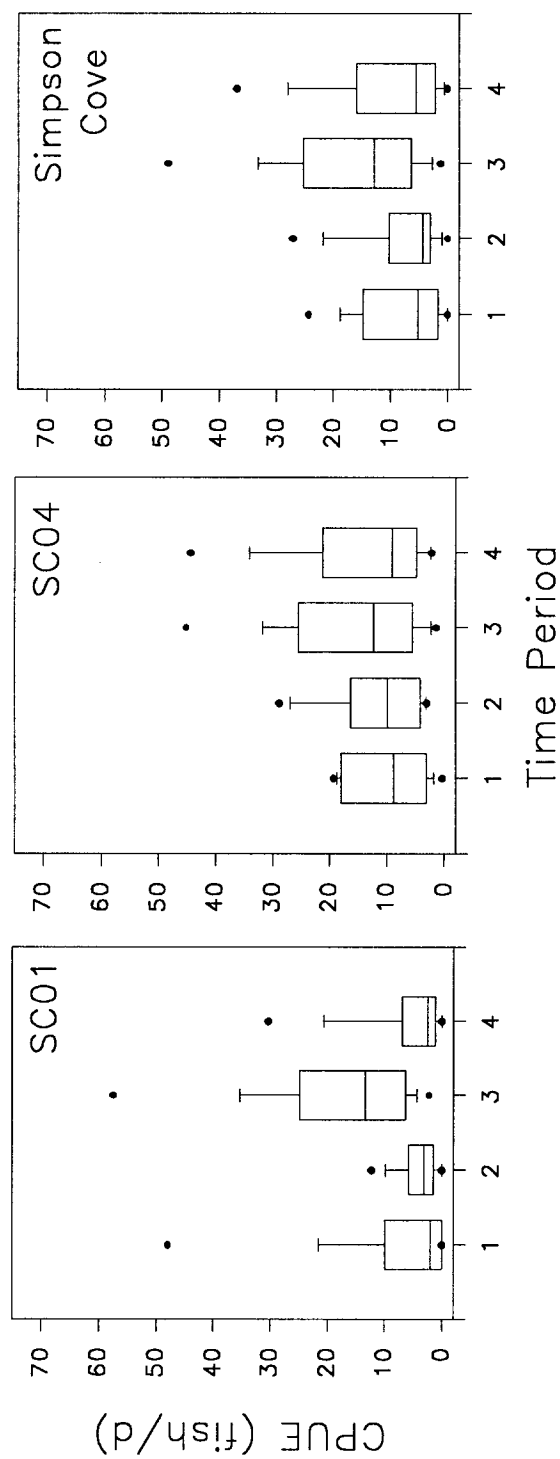


FIGURE 3.4.— Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco ≤ 200 mm FL in Simpson Cove in 1989. 1 = the first sampling day to July 31; 2 = August 1 to August 14; 3 = August 15 to August 31; 4 = September 1 to the last sampling day.

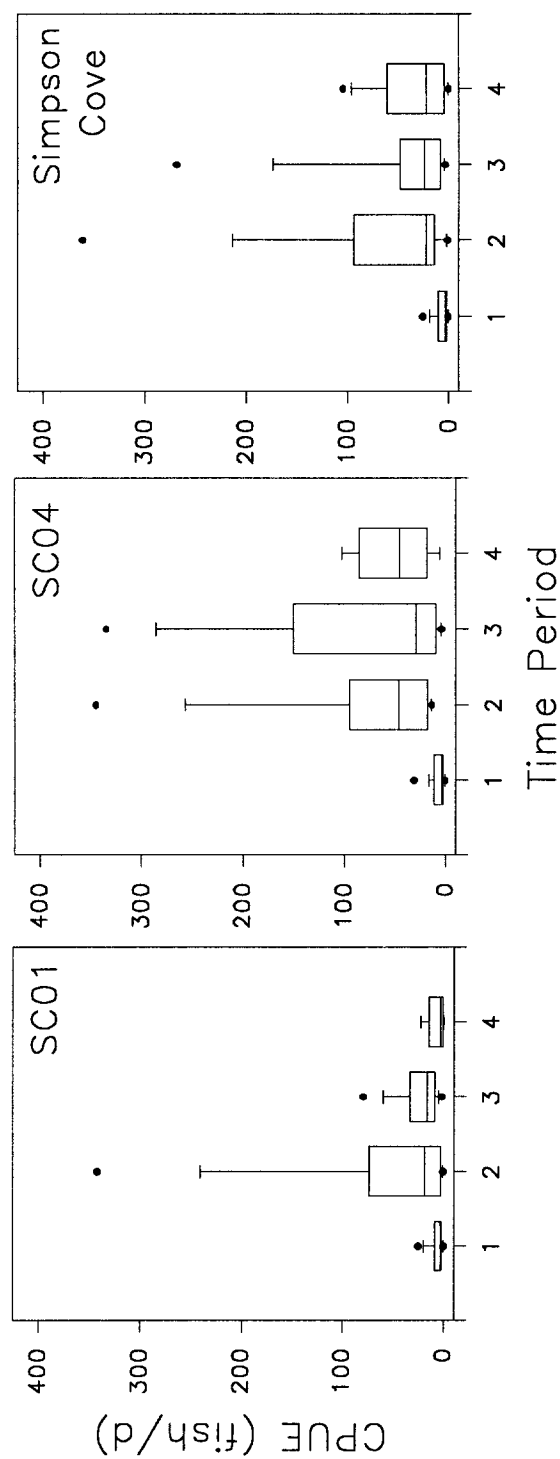


FIGURE 3.5.- Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco ≤ 200 mm FL in Simpson Cove in 1990. 1 = the first sampling day to July 31; 2 = August 1 to August 14; 3 = August 15 to August 31; 4 = September 1 to the last sampling day.

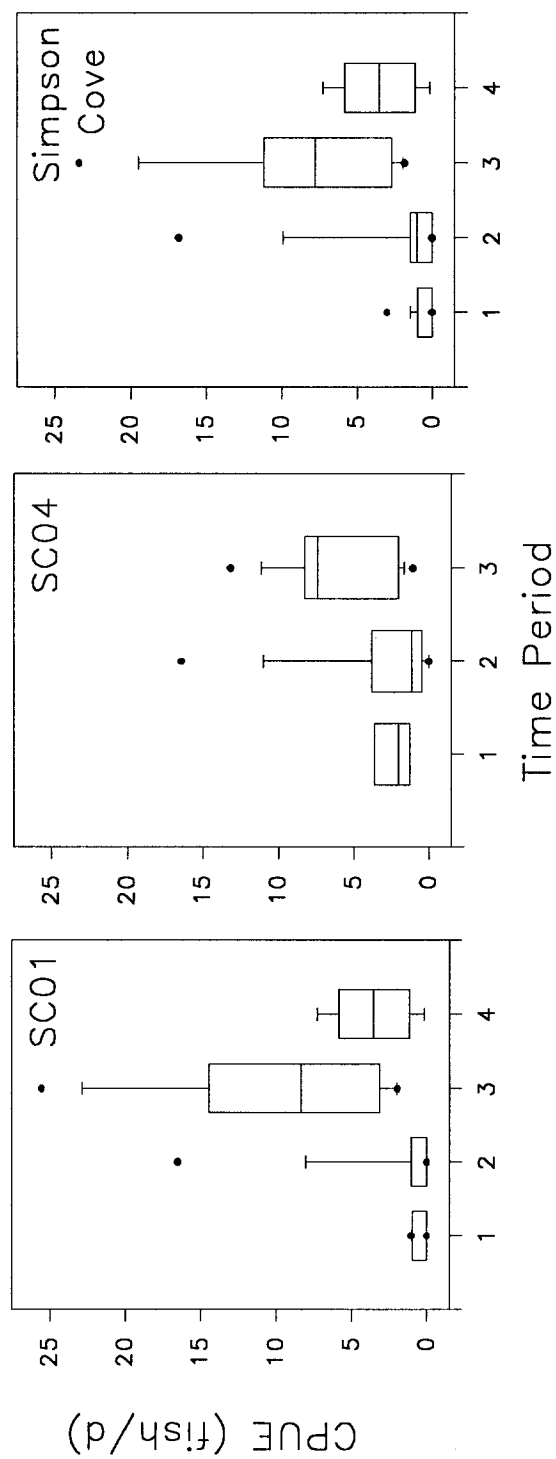


FIGURE 3.6.— Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco ≤ 200 mm FL in Simpson Cove in 1991. 1 = the first sampling day to July 31; 2 = August 1 to August 14; 3 = August 15 to August 31; 4 = September 1 to the last sampling day.

TABLE 3.5.— Comparison of daily CPUE (fish/d) observations among time periods for Arctic cisco ≤ 200 mm FL in Kaktovik Lagoon, 1989-91. For each net station/sampling area those time periods with the same letter, within each year, are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons). Time period 1 corresponds to the period from the first sampling day to July 31. Time period 2 corresponds to the period from August 1 to August 14. Time period 3 corresponds to the period from August 15 to August 31. Time period 4 corresponds to the period from September 1 to the last sampling day.

Time Period	Within year Scheffé groupings		
	1989	1990	1991
Net Station - KL05			
1	B	B	A
2	B	A	A
3	A	A,B	A
4	A	A,B	A
Net Station - KL10			
1	B	B	A
2	B	A,B	A
3	A	B	A
4	A	A	A
Kaktovik Lagoon			
1	B	B	A
2	B	A	A
3	A	A,B	A
4	A	A	A

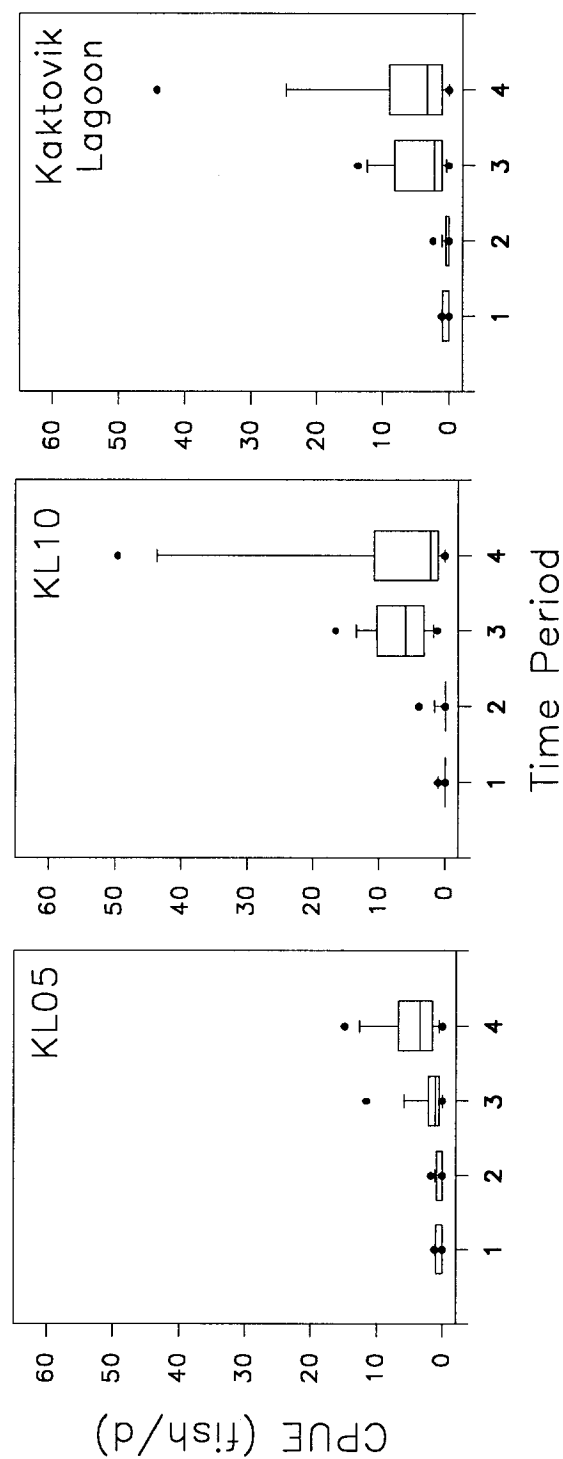


FIGURE 3.7.— Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco ≤ 200 mm FL in Kaktovik Lagoon in 1989. 1 = the first sampling day to July 31; 2 = August 1 to August 14; 3 = August 15 to August 31; 4 = September 1 to the last sampling day.

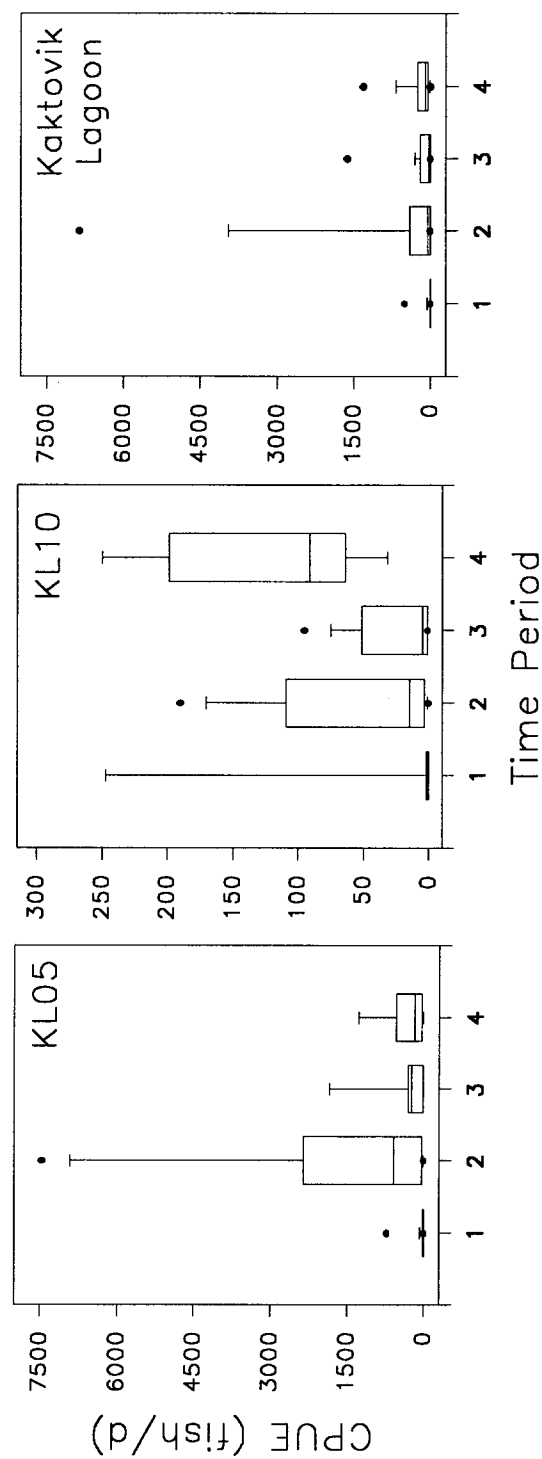


FIGURE 3.8.— Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco ≤ 200 mm FL in Kaktovik Lagoon in 1990. 1 = the first sampling day to July 31; 2 = August 1 to August 14; 3 = August 15 to August 31; 4 = September 1 to the last sampling day.

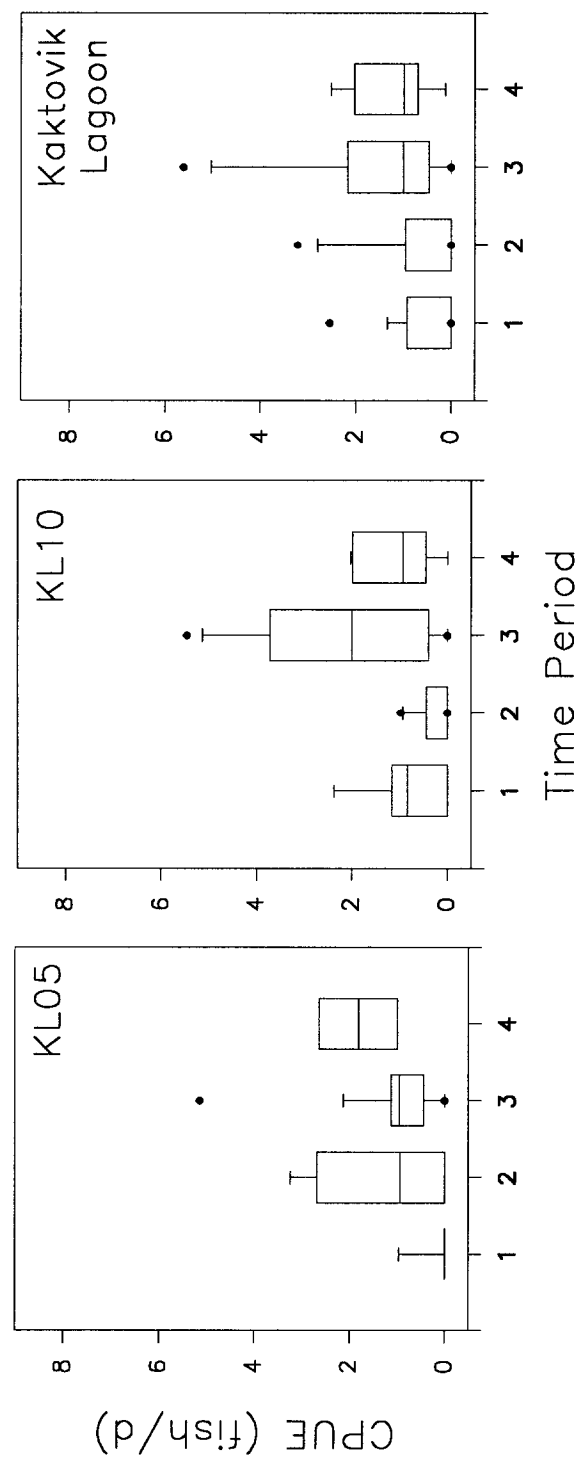


FIGURE 3.9.— Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco ≤ 200 mm FL in Kaktovik Lagoon in 1991. 1 = the first sampling day to July 31; 2 = August 1 to August 14; 3 = August 15 to August 31; 4 = September 1 to the last sampling day.

TABLE 3.6.— Comparison of daily CPUE (fish/d) observations among time periods for Arctic cisco ≤ 200 mm FL in Jago Lagoon, 1989-91. For each net station/sampling area those time periods with the same letter, within each year, are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons). Time period 1 corresponds to the period from the first sampling day to July 31. Time period 2 corresponds to the period from August 1 to August 14. Time period 3 corresponds to the period from August 15 to August 31. Time period 4 corresponds to the period from September 1 to the last sampling day.

Time Period	Within year Scheffé groupings		
	1989	1990	1991
Net Station - JL12			
1	B	C	A
2	B	A	A
3	A	A,B	A
4	A	B,C	A
Net Station - JL14			
1	B	B	A
2	B	A	A
3	A	A,B	A
4	A	B	A
Jago Lagoon			
1	B	C	A
2	B	A	A
3	A	A,B	A
4	A	B,C	A

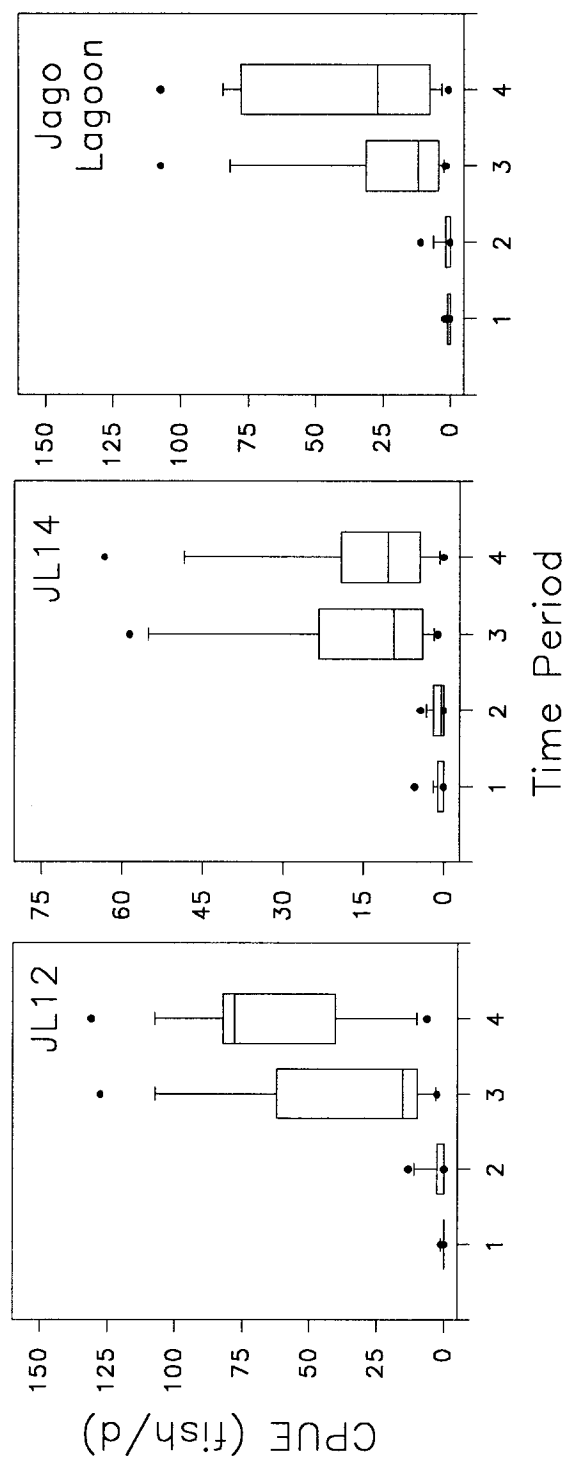


FIGURE 3.10.— Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco \leq 200 mm FL in Jago Lagoon in 1989. 1 = the first sampling day to July 31; 2 = August 1 to August 14; 3 = August 15 to August 31; 4 = September 1 to the last sampling day.

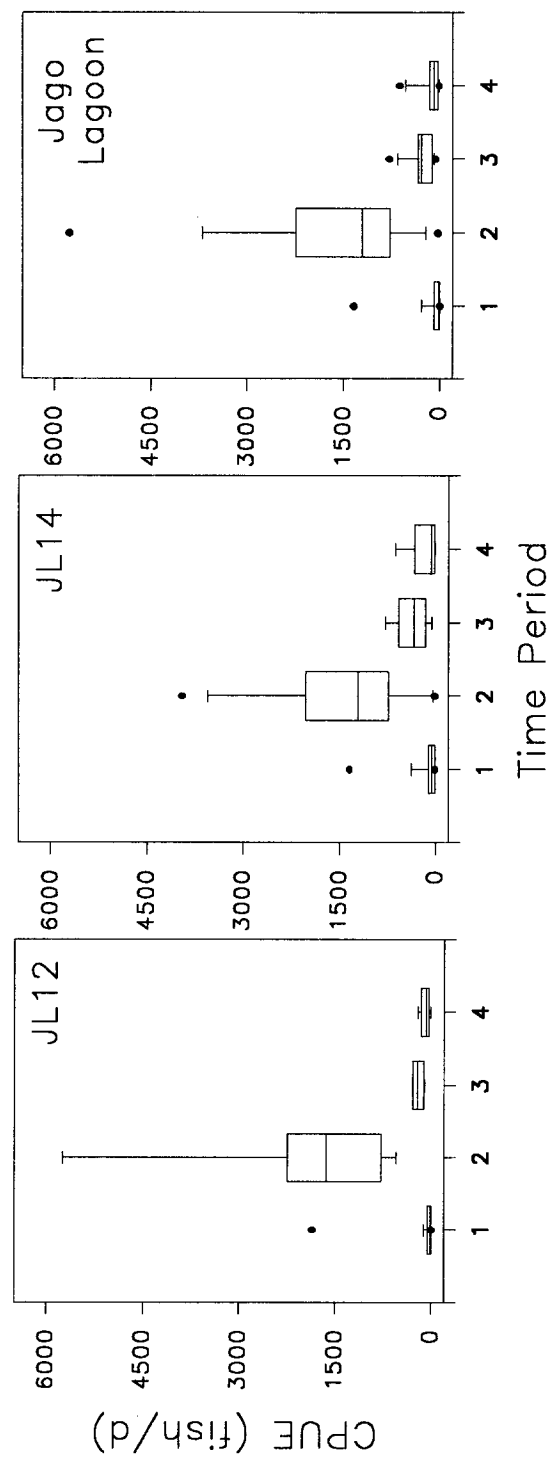


FIGURE 3.11.- Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco \leq 200 mm FL in Jago Lagoon in 1990. 1 = the first sampling day to July 31; 2 = August 1 to August 14; 3 = August 15 to August 31; 4 = September 1 to the last sampling day.

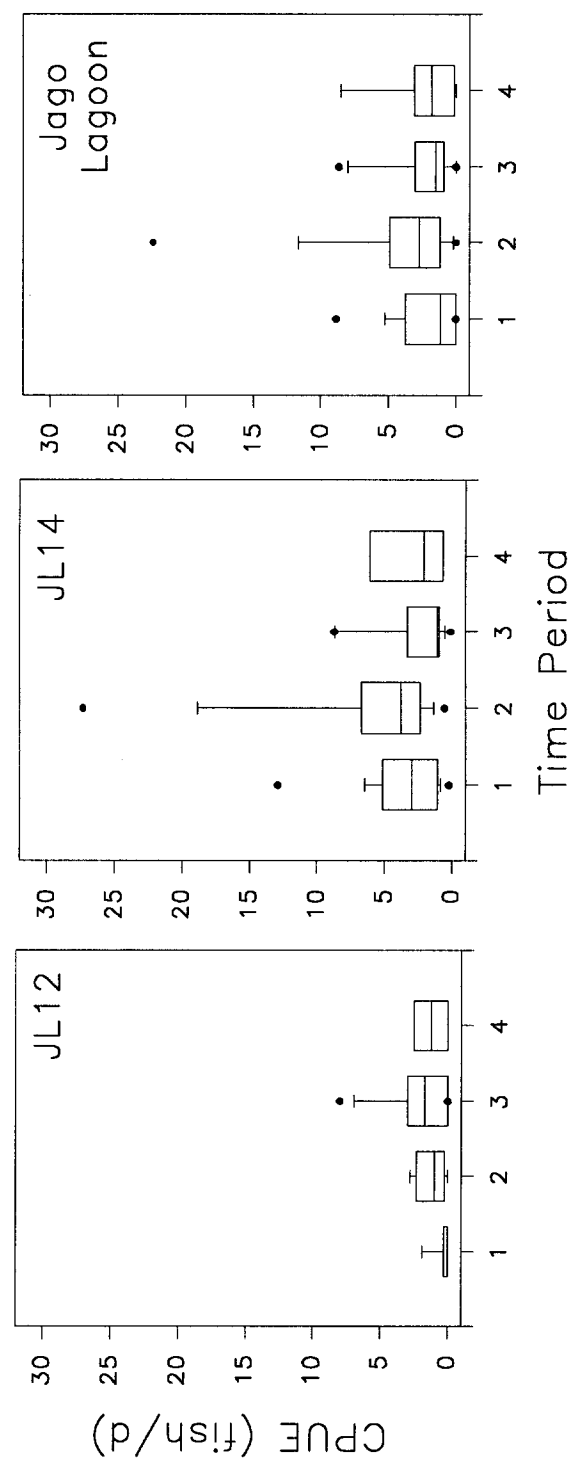


FIGURE 3.12.— Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco \leq 200 mm FL in Jago Lagoon in 1991. 1 = the first sampling day to July 31; 2 = August 1 to August 14; 3 = August 15 to August 31; 4 = September 1 to the last sampling day.

TABLE 3.7.— Comparison of daily CPUE (fish/d) observations among time periods for Arctic cisco ≤ 200 mm FL in Beaufort Lagoon, 1990 and 1991. For each net station/sampling area those time periods with the same letter, within each year, are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons). Time period 1 corresponds to the period from the first sampling day to July 31. Time period 2 corresponds to the period from August 1 to August 14. Time period 3 corresponds to the period from August 15 to August 31. Time period 4 corresponds to the period from September 1 to the last sampling day.

Time Period	Within year Scheffé groupings	
	1990	1991
Net Station - BL02		
1	A,B	C
2	A	B,C
3	A,B	A,B
4	B	A
Net Station - BL04		
1	B	B
2	A,B	A,B
3	A	A
4	A,B	A
Beaufort Lagoon		
1	A	C
2	A	B,C
3	A	A,B
4	A	A

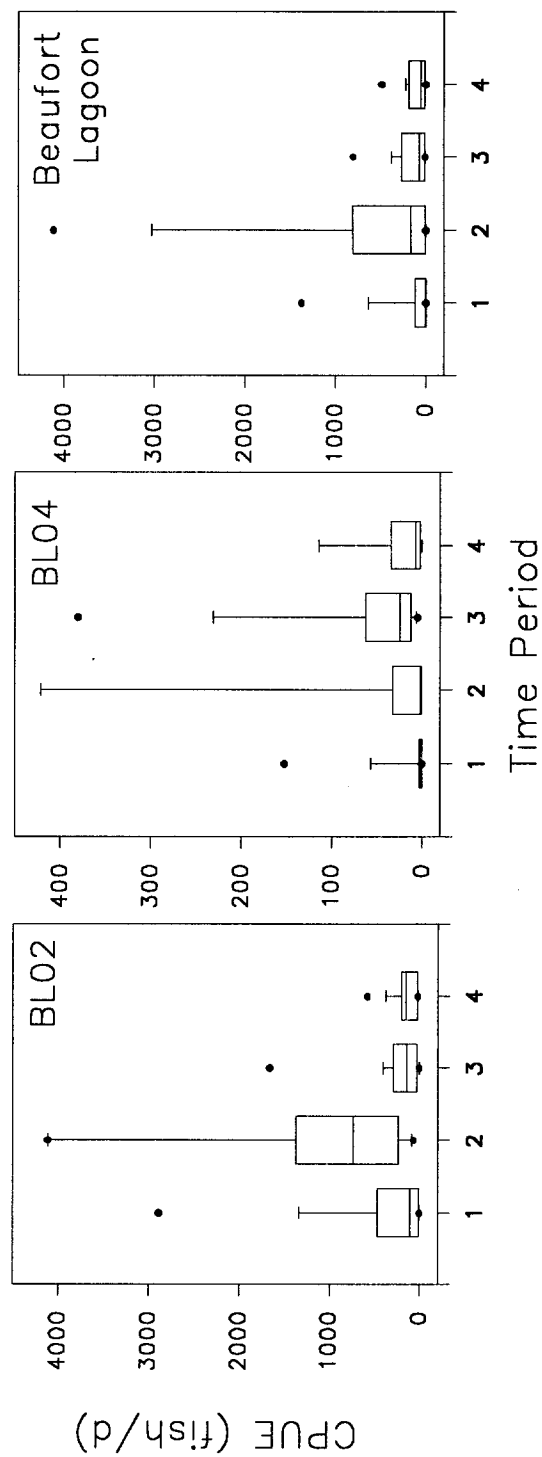


FIGURE 3.13.— Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco \leq 200 mm FL in Beaufort Lagoon in 1990. 1 = the first sampling day to July 31; 2 = August 1 to August 14; 3 = August 15 to August 31; 4 = September 1 to the last sampling day.

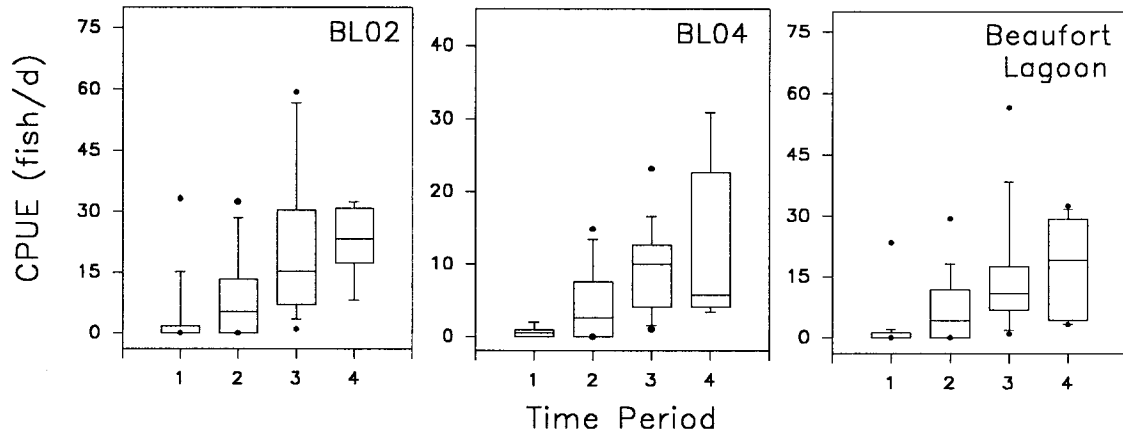


FIGURE 3.14.— Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco ≤ 200 mm FL in Beaufort Lagoon in 1991. 1 = the first sampling day to July 31; 2 = August 1 to August 14; 3 = August 15 to August 31; 4 = September 1 to the last sampling day.

TABLE 3.8.— Comparison of daily CPUE (fish/d) observations among years for Arctic cisco ≤ 200 mm FL. For each net station/sampling area those years with the same letter are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons).

Year	Within location Scheffé groupings		
	Net Station	Net Station	Sampling Area
	SC01	SC04	Simpson Cove
1989	A	A	B
1990	A	A	A
1991	B	B	C
	KL05	KL10	Kaktovik Lagoon
1989	B	B	B
1990	A	A	A
1991	B	B	B
	JL12	JL14	Jago Lagoon
1989	B	B	B
1990	A	A	A
1991	B	B	B
	BL02	BL04	Beaufort Lagoon
1990	A	A	A
1991	B	A	B

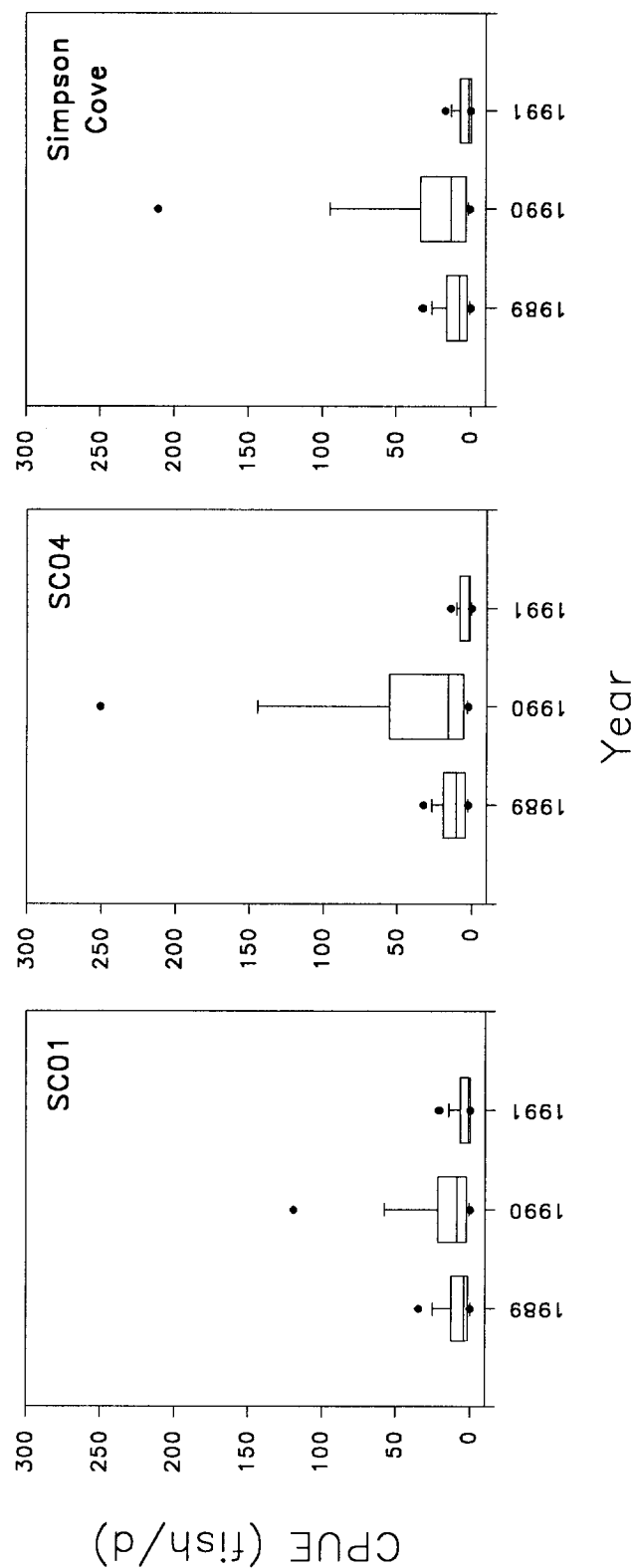


FIGURE 3.15.— Boxplots comparing daily CPUE (fish/d) observations among years for Arctic cisco ≤ 200 mm FL in Simpson Cove.

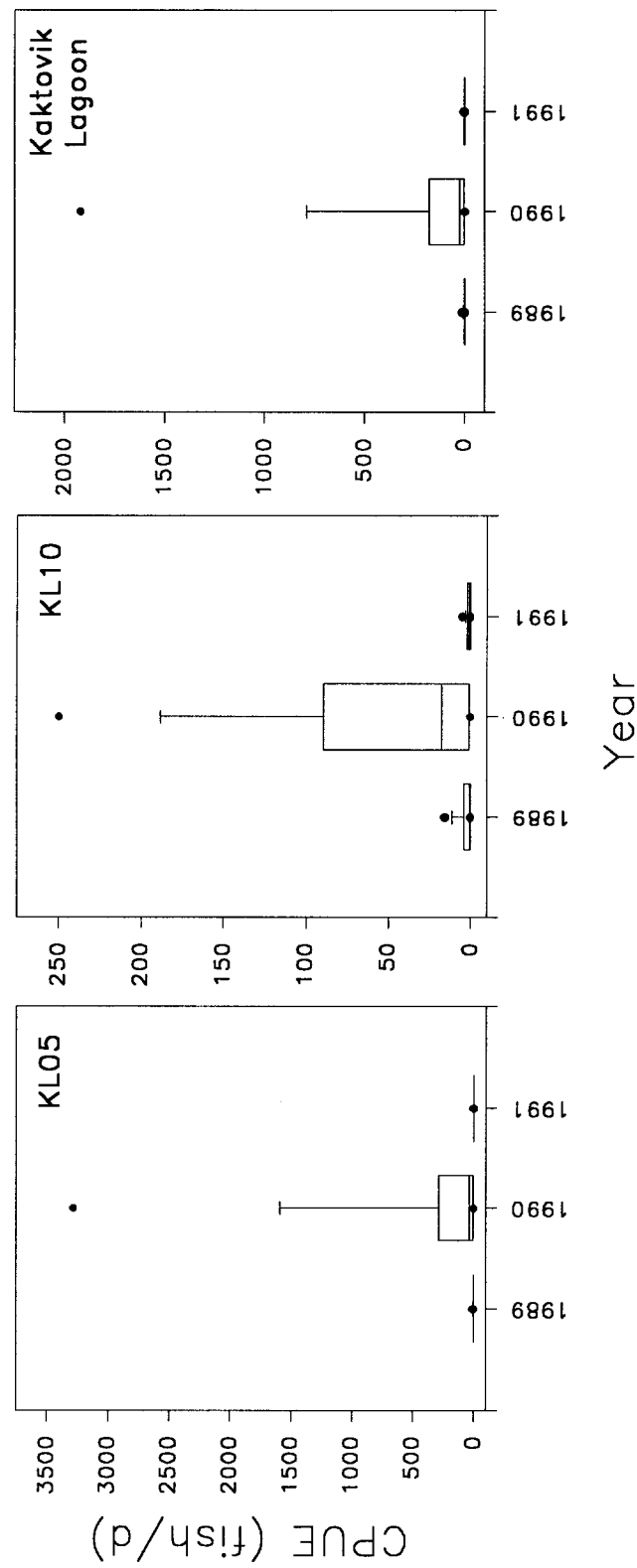


FIGURE 3.16.— Boxplots comparing daily CPUE (fish/d) observations among years for Arctic cisco ≤ 200 mm FL in Kaktovik Lagoon.

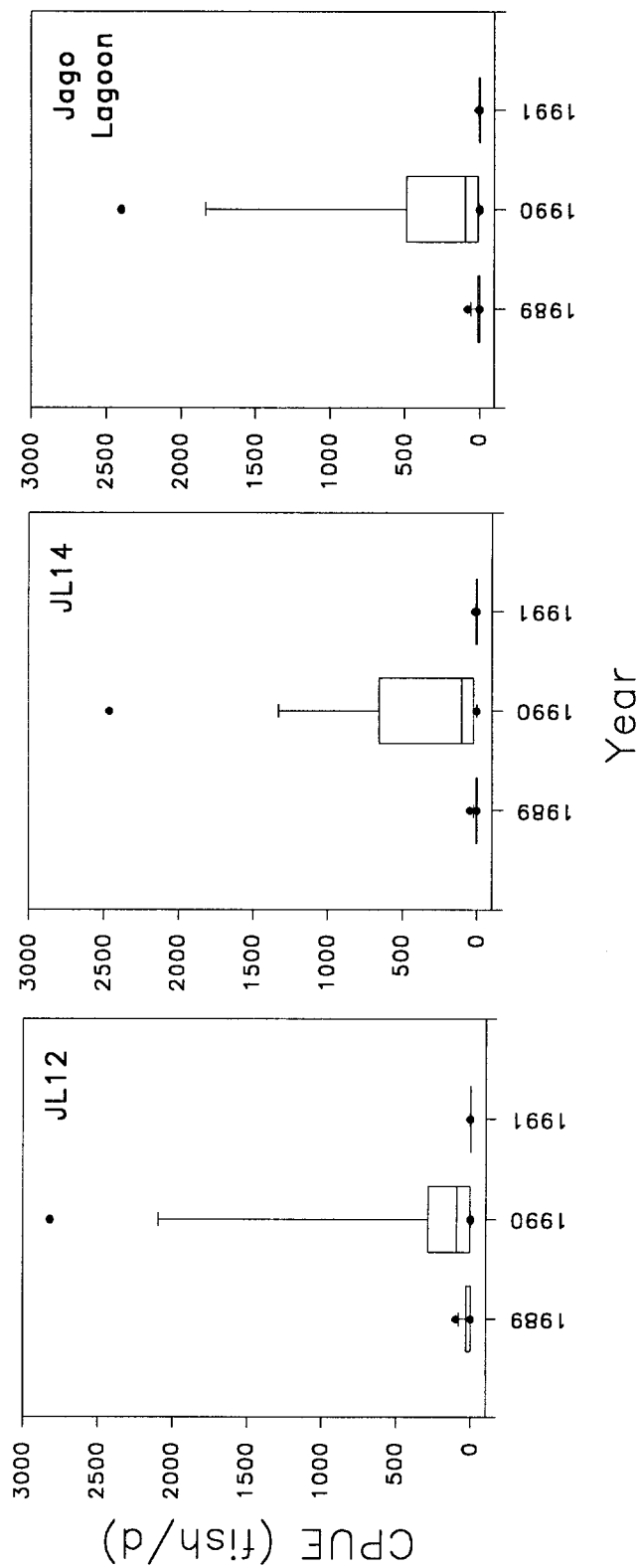


FIGURE 3.17.- Boxplots comparing daily CPUE (fish/d) observations among years for Arctic cisco ≤ 200 mm FL in Jago Lagoon.

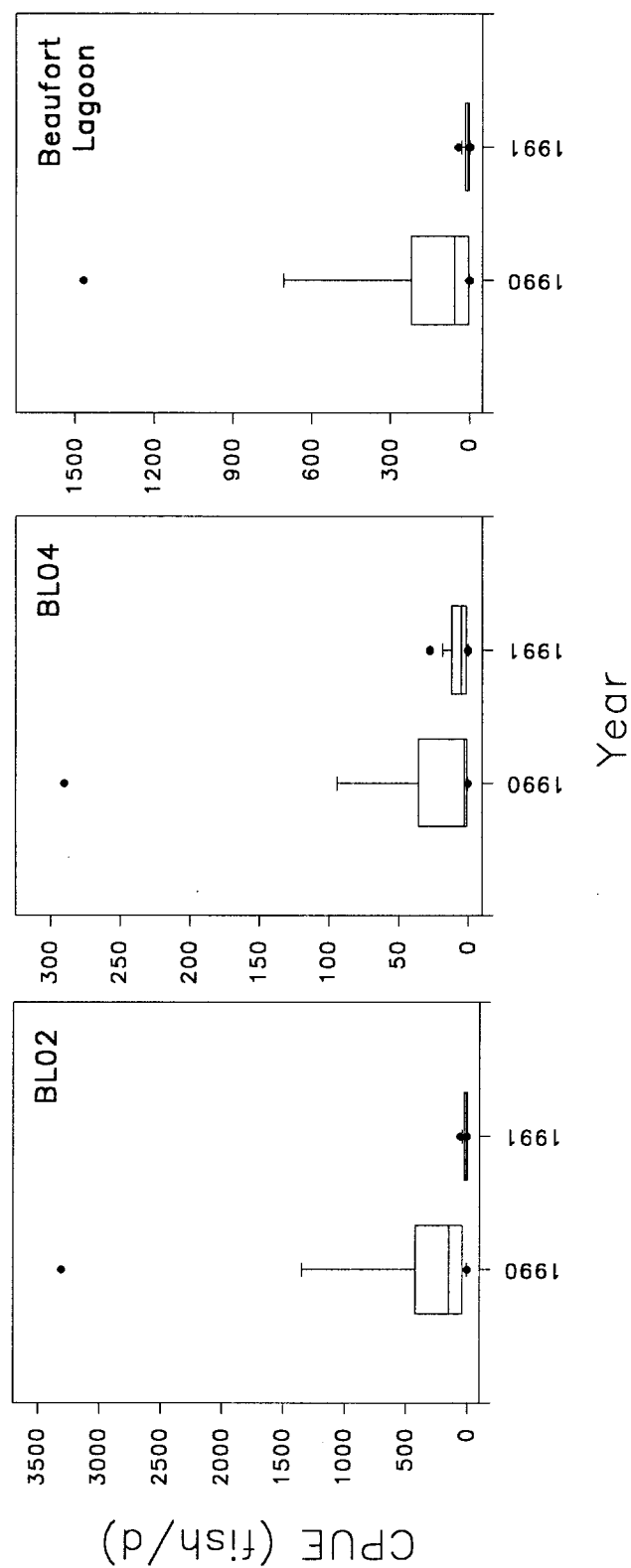


FIGURE 3.18.— Boxplots comparing daily CPUE (fish/d) observations between years for Arctic cisco ≤ 200 mm FL in Beaufort Lagoon.

TABLE 3.9.- Comparison of daily CPUE (fish/d) observations among years for Arctic ≤ 200 mm Fl in Simpson Cove. For each net station/sampling area those years with the same letter, within the time period, are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons). Locations with dashed lines were not sampled during that year.

Within location Scheffé groupings			
Year	SC01	SC04	Simpson Cove
Time Period 1 - first day to July 31			
1989	A	A	A
1990	A	A	A
1991	B	A	B
Time Period 2 - August 1 to August 14			
1989	A,B	B	B
1990	A	A	A
1991	B	C	C
Time Period 3 - August 15 to August 31			
1989	A	A,B	A,B
1990	A	A	A
1991	A	B	B
Time Period 4 - September 1 to last day			
1989	A	A	A,B
1990	A	B	A
1991	A	--	B

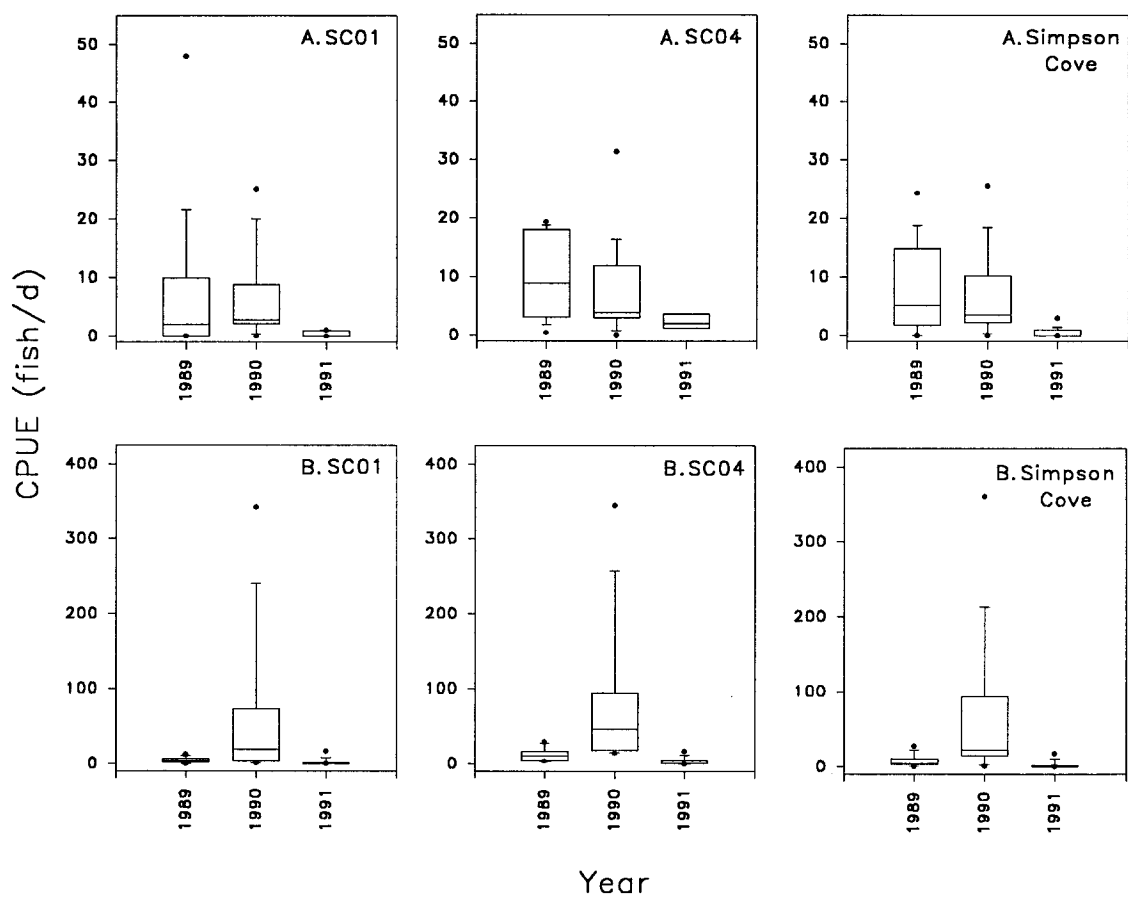


FIGURE 3.19.— Boxplots comparing daily CPUE (fish/d) observations among years for Arctic cisco ≤ 200 mm FL in Simpson Cove. A = time period 1, the first sampling day to July 31. B = time period 2, August 1 to August 14.

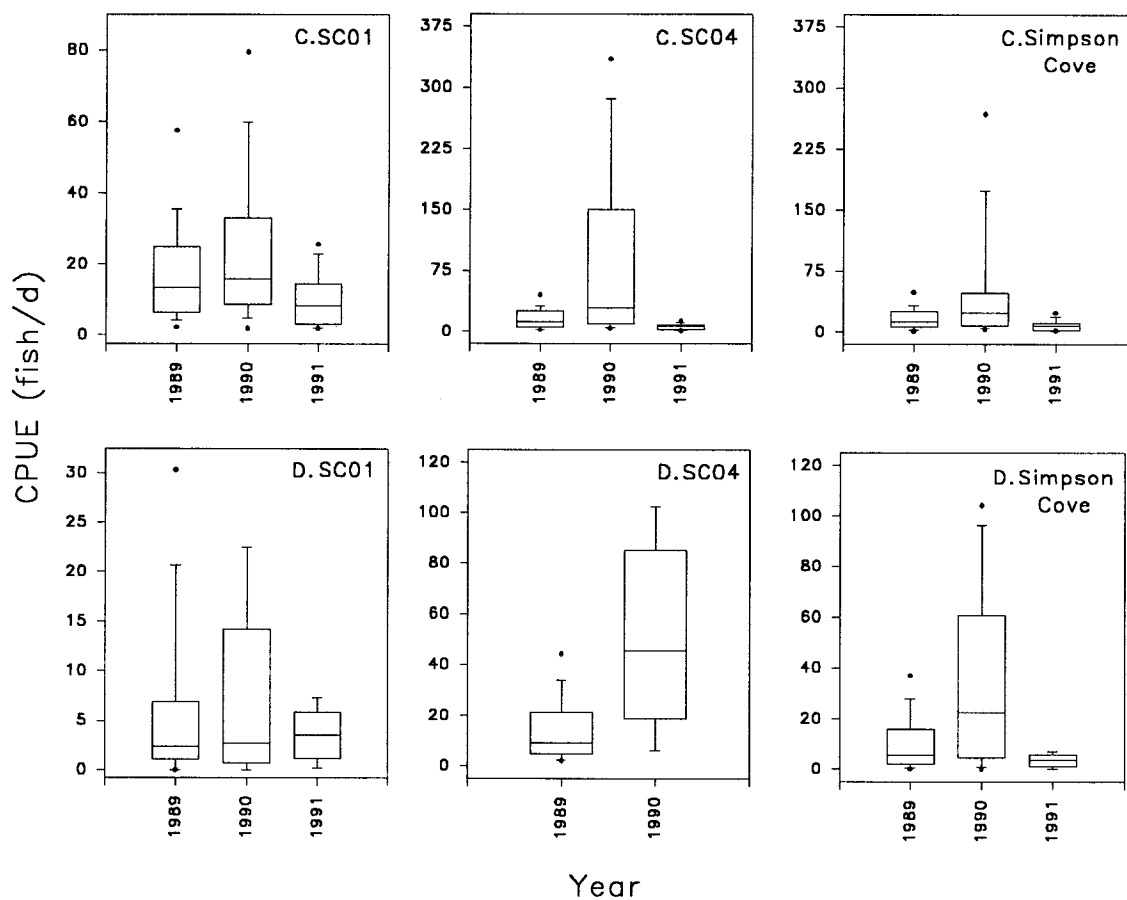


FIGURE 3.20.— Boxplots comparing daily CPUE (fish/d) observations among years for Arctic cisco ≤ 200 mm FL in Simpson Cove. C = time period 3, August 15 to August 31. D = time period 4, September 1 to the last sampling day.

3.19A). During the time period from August 1 to August 14 net station SC01 daily catch rates were higher in 1990 than in 1991 (Table 3.9; Figure 3.19B). After August 14 daily catch rates at net station SC01 did not differ among years (Table 3.9; Figure 3.20). At net station SC04 daily catch rates during July did not differ among years. Daily catch rates of small Arctic cisco at net station SC04 during early August were higher in 1990 than in 1989 or 1991. For the latter half of August 1990 daily catch rates were higher than those in 1991. Low sampling area daily catch rates for 1991 were observed during all time periods. After August 14, Simpson Cove daily catch rates differed only in that those observed in 1990 were higher than those observed during 1991.

Daily catch rates of small Arctic cisco were highest during the 1990 sampling season at net station KL05 (Table 3.10; Figures 3.21-3.22). At net station KL10 daily catch rates in July did not differ among years. From August 1 to August 14 and after September 1 at net station KL10 1990 daily catch rates were the highest among the years. During the latter half of August at net station KL10 daily catch rates decreased during the four years of study. Prior to August 15 and after September 1, Kaktovik Lagoon sampling area daily catch rates for small Arctic cisco in 1990 were the highest observed. In the latter half of August sampling area daily catch rates differed only in that those in 1990 were only higher than those in 1991.

Prior to September 1 daily catch rates at net stations JL12, JL14 and in the Jago Lagoon sampling area were highest during 1990 (Table 3.11; Figures 3.23-3.24). After September 1 at all Jago Lagoon locations 1990 daily catch rates were only higher than those observed for 1991.

Net station BL02 daily catch rates of small Arctic cisco were highest during the 1990 sampling season (Table 3.12; Figures 3.25-3.26). Comparisons of daily catch rates at net station BL04 differed only in late August when those in 1990 were higher than those in 1991. Prior to September 1 Beaufort Lagoon sampling area daily catch rates were higher in 1990 than in 1991. After September 1 daily catch rates did not differ between years.

Relative Abundance and Distribution: Arctic cisco > 200 mm FL

Two-way ANOVA.—Results of the two-way analysis of variance on log-transformed daily catch rates of large Arctic cisco (> 200 mm FL) are presented in Table 3.13. The year and area main effects and the interaction term were all highly significant ($P < 0.0001$), although the overall model failed to explain much of the observed variation ($R^2 = 0.21$). A breakdown of the model sum of squares (SS) indicated that area (SS = 151.46) was a greater source of variation than was year (SS = 49.52); i.e., from 1989 to 1990, daily catch rates of large Arctic cisco varied more between sampling areas than from year to year. Reversing the order in which the main effects entered the computer algorithm did not alter the results. Means comparisons for the main effects should be viewed with caution due to the significant interaction effect. While the means comparisons of the interaction factor levels exhibited extensive linkages, the results suggest daily catch rates were generally higher in Simpson Cove during all three years.

TABLE 3.10.- Comparison of daily CPUE (fish/d) observations among years for Arctic cisco ≤ 200 mm FL in Kaktovik Lagoon. For each net station/sampling area those years with the same letter, within the time period, are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons).

Within location Scheffé groupings			
Year	KL05	KL10	Kaktovik Lagoon
Time Period 1 - first day to July 31			
1989	B	A	B
1990	A	A	A
1991	B	A	B
Time Period 2 - August 1 to August 14			
1989	B	A	B
1990	A	A,B	A
1991	B	B	B
Time Period 3 - August 15 to August 31			
1989	B	B	A,B
1990	A	A	A
1991	B	B	B
Time Period 4 - September 1 to last day			
1989	B	B	B
1990	A	A	A
1991	B	B	B

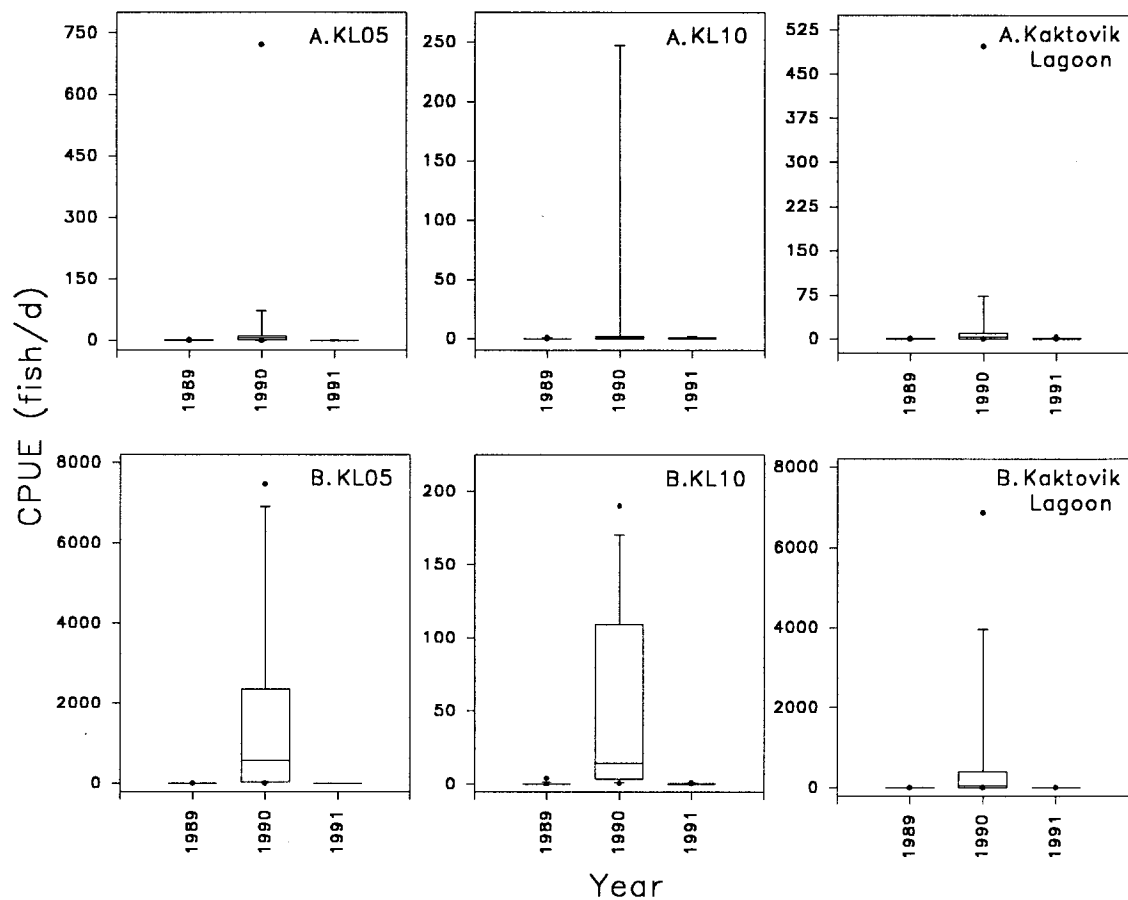


FIGURE 3.21.— Boxplots comparing daily CPUE (fish/d) observations among years for Arctic cisco ≤ 200 mm FL in Kaktovik Lagoon. A = time period 1, the first sampling day to July 31. B = time period 2, August 1 to August 14.

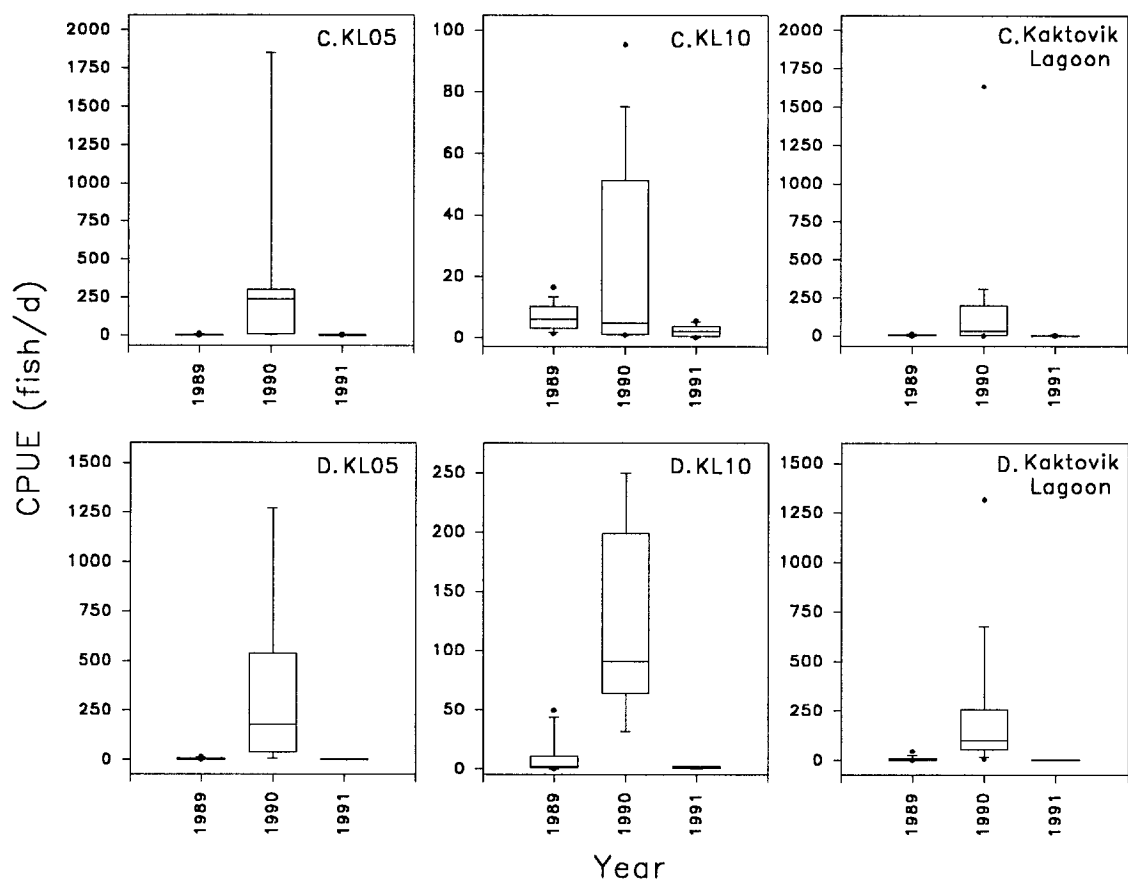


FIGURE 3.22.- Boxplots comparing daily CPUE (fish/d) observations among years for Arctic cisco ≤ 200 mm FL in Kaktovik Lagoon. C = time period 3, August 15 to August 31. D = time period 4, September 1 to the last sampling day.

TABLE 3.11.— Comparison of daily CPUE (fish/d) observations among years for Arctic cisco ≤ 200 mm FL in Jago Lagoon. For each net station/sampling area those years with the same letter, within the time period, are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons).

Within location Scheffé groupings			
Year	JL12	JL14	Jago Lagoon
Time Period 1 - first day to July 31			
1989	B	C	C
1990	A	A	A
1991	B	B	B
Time Period 2 - August 1 to August 14			
1989	B	C	C
1990	A	A	A
1991	B	B	B
Time Period 3 - August 15 to August 31			
1989	B	B	B
1990	A	A	A
1991	C	C	C
Time Period 4 - September 1 to last day			
1989	A,B	A,B	A
1990	A	A	A
1991	B	B	B

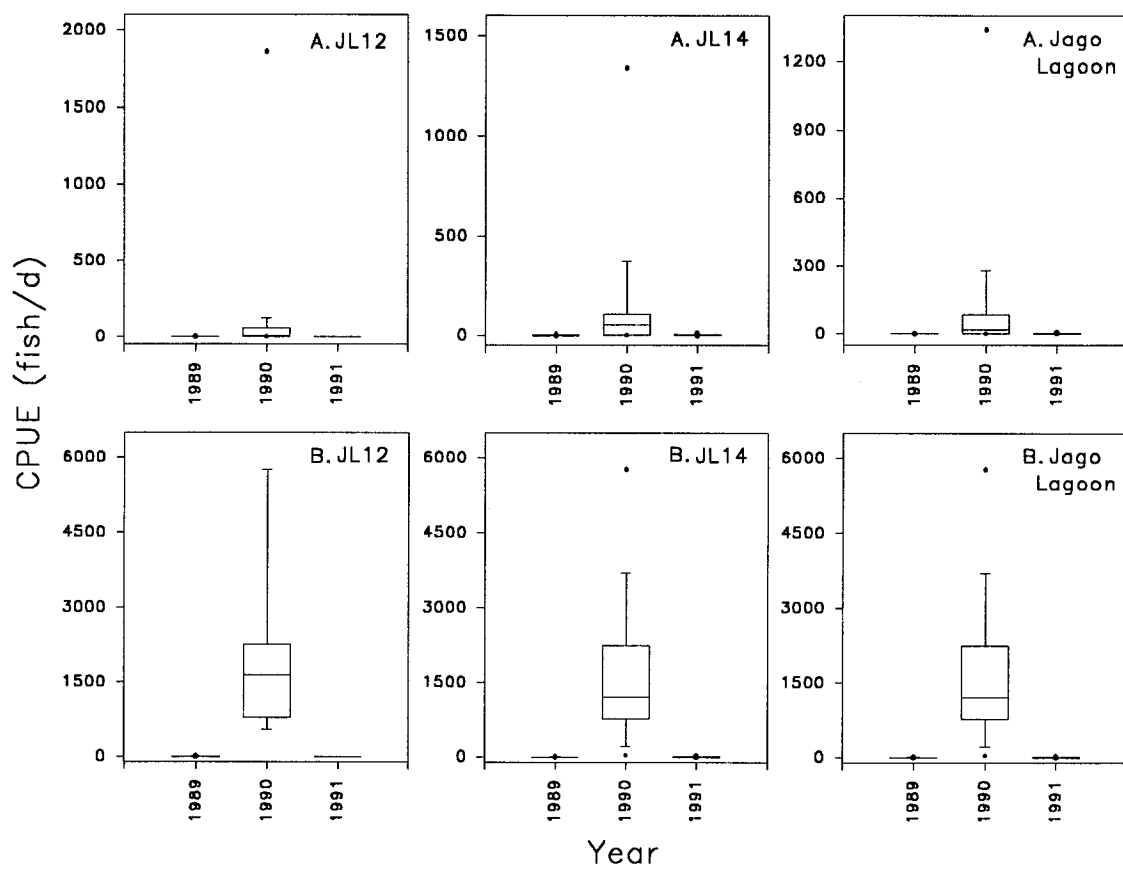


FIGURE 3.23.— Boxplots comparing daily CPUE (fish/d) observations among years for Arctic cisco ≤ 200 mm FL in Jago Lagoon. A = time period 1, the first sampling day to July 31. B = time period 2, August 1 to August 14.

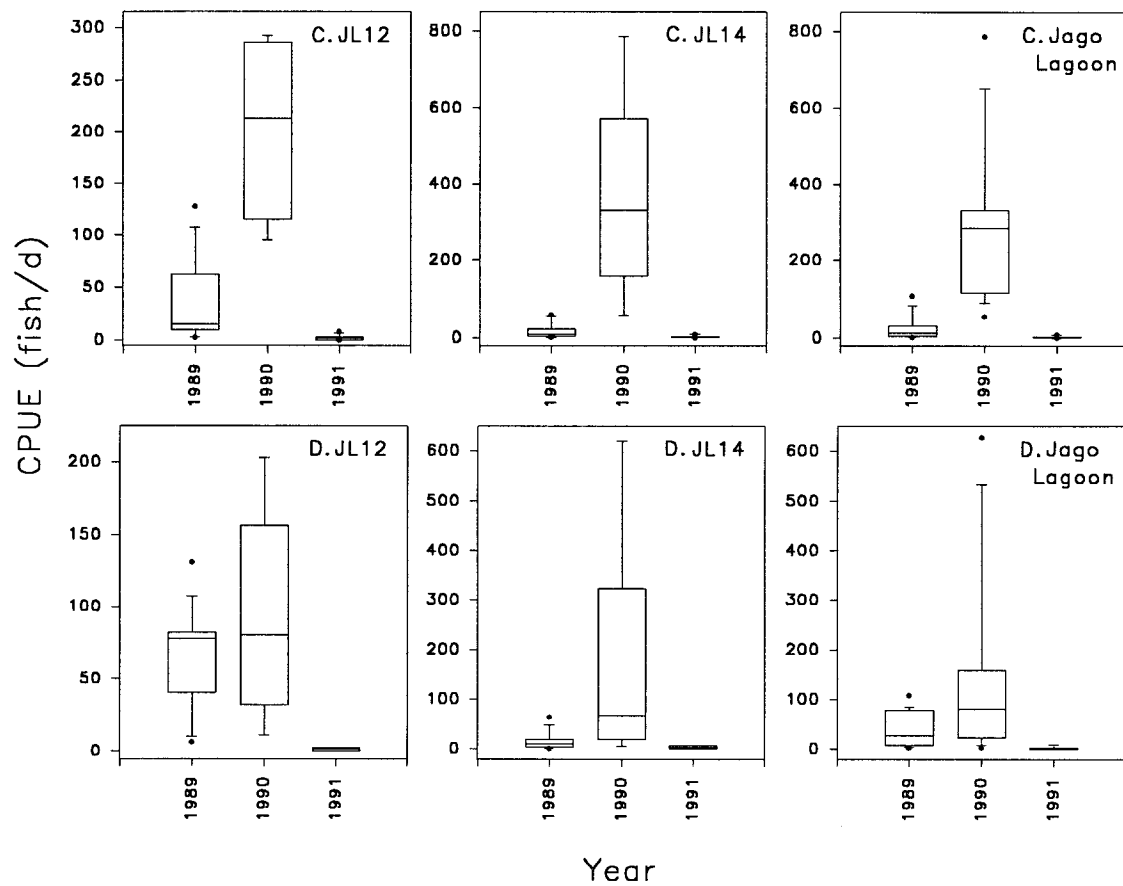


FIGURE 3.24.— Boxplots comparing daily CPUE (fish/d) observations among years for Arctic cisco ≤ 200 mm FL in Jago Lagoon. C = time period 3, August 15 to August 31. D = time period 4, September 1 to the last sampling day.

TABLE 3.12.— Comparison of daily CPUE (fish/d) observations between years for Arctic cisco ≤ 200 mm FL in Beaufort Lagoon. For each net station/sampling area those years with the same letter, within the same time period, are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons).

Within location Scheffé groupings			
Year	BL02	BL04	Beaufort Lagoon
Time Period 1 - first day to July 31			
1990	A	A	A
1991	B	A	B
Time Period 2 - August 1 to August 14			
1990	A	A	A
1991	B	A	B
Time Period 3 - August 15 to August 31			
1990	A	A	A
1991	B	B	B
Time Period 4 - September 1 to last day			
1990	A	A	A
1991	B	A	A

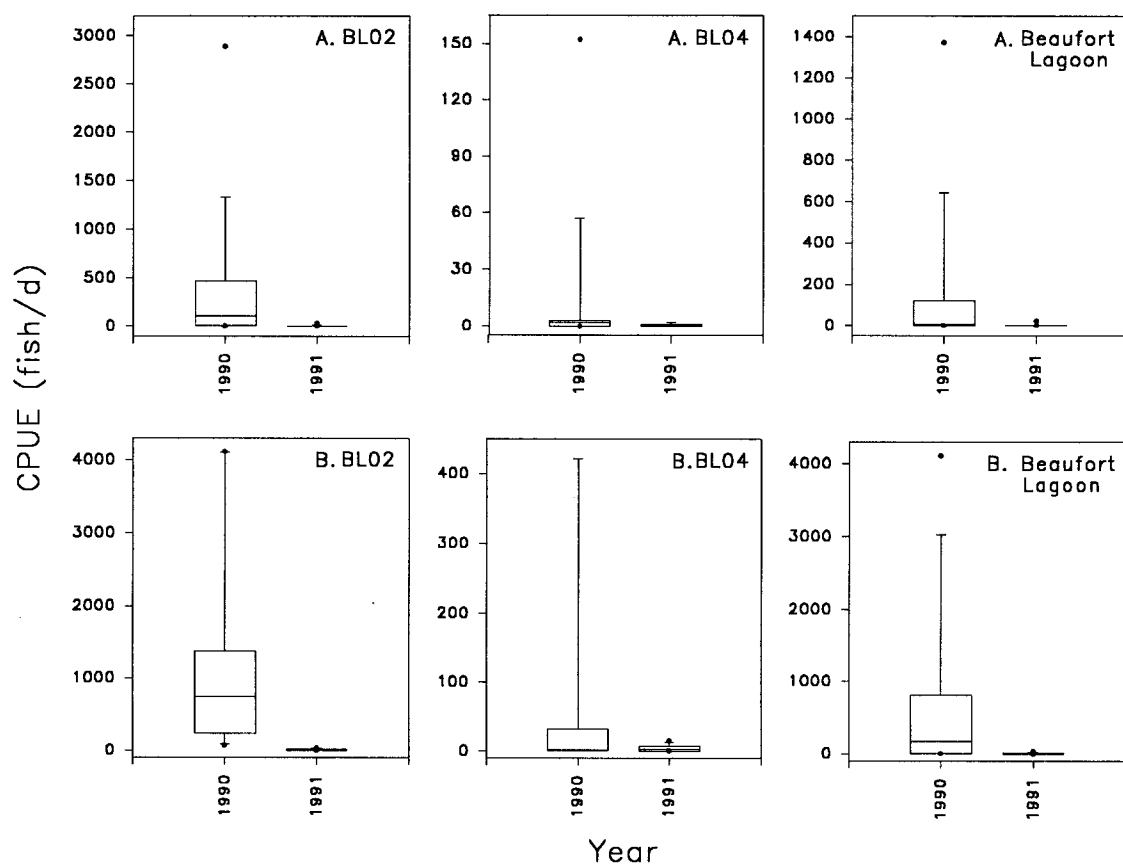


FIGURE 3.25.— Boxplots comparing daily CPUE (fish/d) observations between years for Arctic cisco ≤ 200 mm FL in Beaufort Lagoon. A = time period 1, the first sampling day to July 31. B = time period 2, August 1 to August 14.

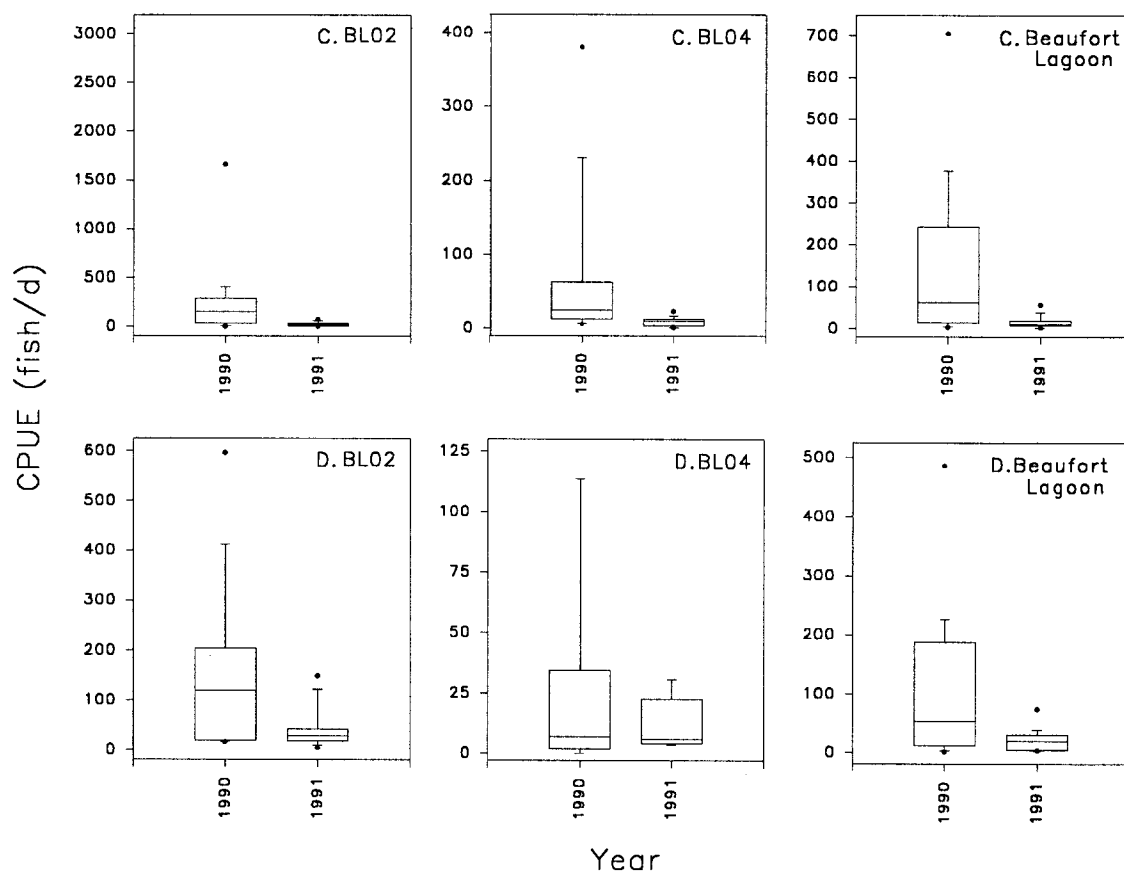


FIGURE 3.26.— Boxplots comparing daily CPUE (fish/d) observations between years for Arctic cisco ≤ 200 mm FL in Beaufort Lagoon. C = time period 3, August 15 to August 31. D = time period 4, September 1 to the last sampling day.

TABLE 3.13.— Two factor analysis of variance on log-transformed daily catch rates ($\ln(\text{CPUE}+1)$) and Tukey means comparisons for Arctic cisco > 200 mm FL from coastal waters of the Arctic Refuge. Effects followed by the same letter are not significantly different ($P > 0.05$). Mean_g = geometric mean.

Source	df	Sum of squares	Mean square	F-value	P-value
Model					
Year	2	49.52	24.76	29.98	0.0001
Area	3	151.46	50.49	61.13	0.0001
YearxArea	5	26.38	5.28	6.39	0.0001
Error	1006	830.89	0.83		
Total	1016	1058.25			

Year	Mean _g	Tukey grouping
1989	1.36	A
1991	1.15	B
1990	0.83	C

Area	Mean _g	Tukey grouping
Simpson	1.72	A
Jago	0.93	B
Kaktovik	0.84	B
Beaufort	0.74	B

YearxArea	Mean _g	Tukey grouping
1989-Simpson	2.03	A
1991-Simpson	1.60	A B
1990-Simpson	1.47	B C
1989-Jago	1.22	B C D
1991-Beaufort	1.15	C D E
1991-Kaktovik	0.99	D E F
1991-Jago	0.84	D E F
1989-Kaktovik	0.78	E F G
1990-Kaktovik	0.77	E F G
1990-Jago	0.66	F G
1990-Beaufort	0.38	G

Spatial differences.— Within-year comparisons of daily catch rates displayed differences in the relative abundance of large Arctic cisco among net stations (Table 3.14; Figure 3.27). During 1989, net stations SC01 and SC04 had significantly higher daily catch rates than net stations KL05, KL10, and JL14. Net stations within a sampling area did not differ significantly from each other. In 1990, net station SC01 had higher large Arctic cisco daily catch rates than net stations KL10, JL12, JL14, BL02, and BL04. Daily catch rates among net stations SC01, SC04, and KL05 did not differ significantly. A similar pattern is evident for the 1991 sampling season. Large Arctic cisco daily catch rates at net station SC01 were higher than those at all other net stations, except net station BL04.

Differences in the daily catch rates of large Arctic cisco were noted among sampling areas (Table 3.15; Figure 3.28). During 1989 daily catch rates were highest in Simpson Cove followed by Jago Lagoon. The lowest daily catch rates were observed in Kaktovik Lagoon. In 1990 daily catch rates were highest in Simpson Cove. Daily catch rates decreased moving eastward to Kaktovik and Jago lagoons. The lowest daily catch rates were observed in Beaufort Lagoon. Large Arctic cisco 1991 daily catch rates in Simpson Cove were higher than those in Kaktovik and Jago lagoons. Simpson Cove and Beaufort Lagoon daily catch rates did not differ significantly. No differences were noted among the daily catch rates for Kaktovik, Jago and Beaufort lagoons.

Temporal differences.— In 1989 at net stations SC01, SC04, and in the Simpson Cove sampling area the time period from August 15 to August 31 had some of the highest daily catch rates observed (Table 3.16; Figure 3.29). Throughout the 1990 sampling season large Arctic cisco daily catch rates decreased at net stations SC01, SC04 and in the Simpson Cove sampling area (Table 3.16; Figure 3.30). At net station SC01, in 1991, daily catch rates were stable until September 1, after which they declined (Table 3.16; Figure 3.31). Daily catch rates were stable during the 1991 sampling season at net station SC04 and in the Simpson Cove sampling area.

Daily rates at net station KL05 declined during the sampling seasons of 1989 and 1990 (Table 3.17; Figures 3.32-3.33). During 1991 large Arctic cisco daily catch rates were stable during the sampling season (Table 3.17; Figure 3.34). At net station KL10 daily catch rates increased between early and late August in 1989. Large Arctic cisco daily catch rates were stable during the sampling seasons of 1990 and 1991 at net station KL10. In the Kaktovik Lagoon sampling area daily catch rates were stable during 1989. During 1990 and 1991 sampling area daily catch rates were stable among at least 3 of the 4 time periods.

Large Arctic cisco daily catch rates at net stations JL12 (1989) and JL14 (1989, 1990) and in the Jago Lagoon sampling area (1989, 1990) had a final decrease after September 1 (Table 3.18; Figures 3.35-3.36). Daily catch rates at net station JL12 in 1990 were stable. No differences in daily catch rates during the 1991 sampling season were found at net stations JL12, JL14, or in the Jago Lagoon sampling area (Table 3.18; Figure 3.37).

TABLE 3.14.— Comparison of daily CPUE (fish/d) observations among net stations for Arctic cisco > 200 mm FL in Arctic Refuge coastal waters, 1989-1991. Within each year those net stations with the same letter are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons).

Station	Within year Scheffé groupings		
	1989	1990	1991
SC01	A,B	A	A
SC04	A	A,B	D
KL05	D	A,B	B,C,D
KL10	D,C	C,D	B,C,D
JL12	B,C	B,C,D	B,C
JL14	C,D	B,C	C,D
BL02		D	B,C,D
BL04		B,C	A,B

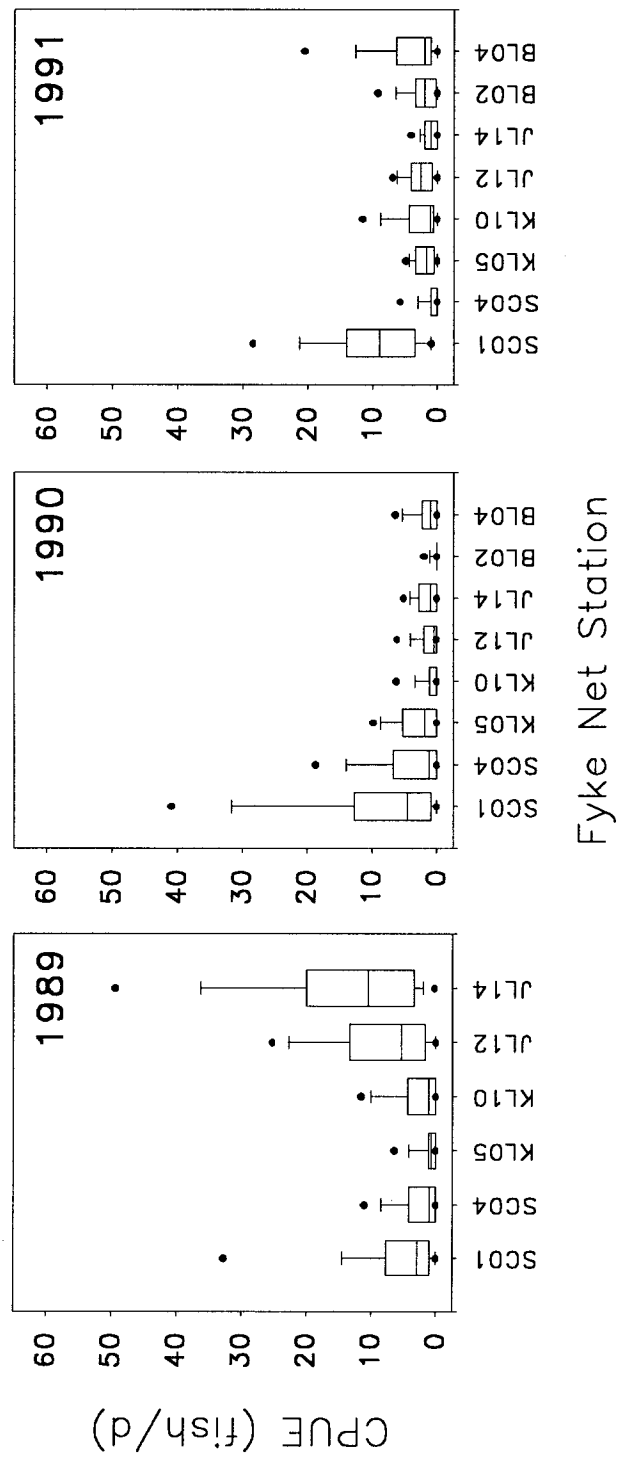


FIGURE 3.27.— Boxplots comparing daily CPUE (fish/d) observations among net stations for Arctic cisco > 200 mm FL in Arctic Refuge coastal waters, 1989-1991.

TABLE 3.15.— Comparison of daily CPUE (fish/d) observations among sampling areas for Arctic cisco > 200 mm FL in Arctic Refuge coastal waters, 1989-1991. Within each year those sampling areas with the same letter are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons).

Sampling area	Within year Scheffé groupings		
	1989	1990	1991
Simpson Cove	A	A	A
Kaktovik Lagoon	C	B	B
Jago Lagoon	B	B,C	B
Beaufort Lagoon		C	A,B

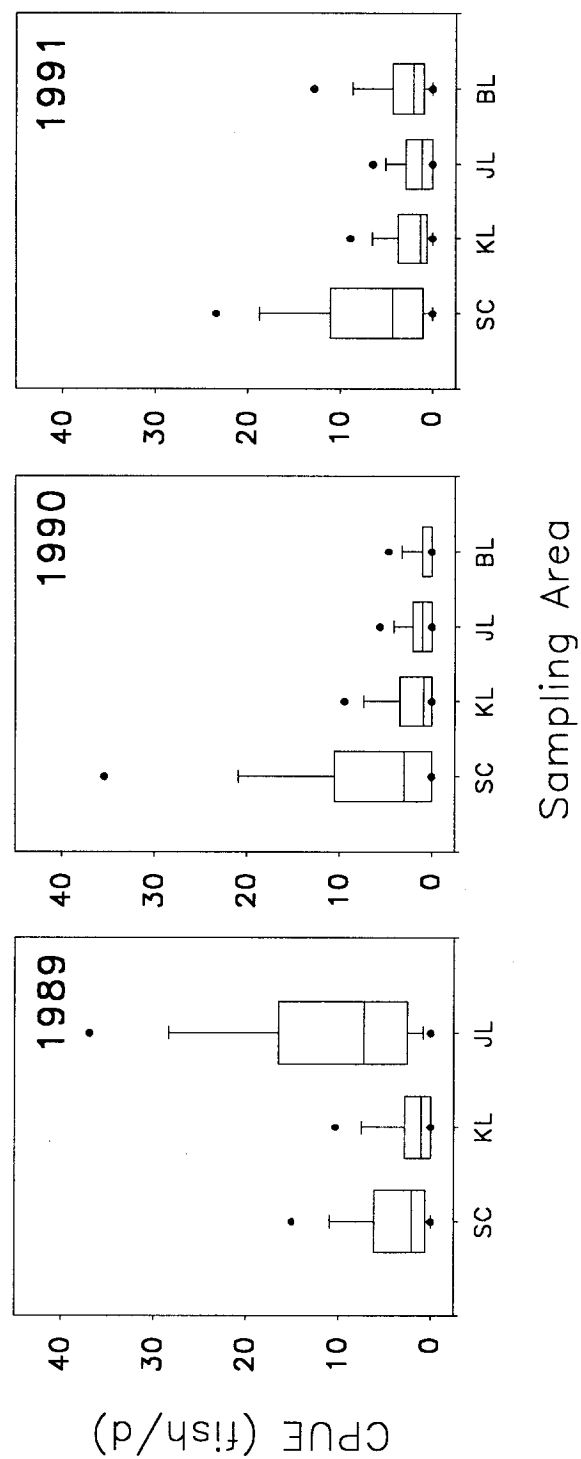


FIGURE 3.28.— Boxplots comparing daily CPUE (fish/d) observations among sampling areas for Arctic cisco > 200 mm FL in Arctic Refuge coastal waters, 1989-1991.

TABLE 3.16.— Comparison of daily CPUE (fish/d) observations among time periods for Arctic cisco > 200 mm FL in Simpson Cove, 1989-91. For each net station/sampling area those time periods with the same letter, within each year, are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons). Time period 1 corresponds to the period from the first sampling day to July 31. Time period 2 corresponds to the period from August 1 to August 14. Time period 3 corresponds to the period from August 15 to August 31. Time period 4 corresponds to the period from September 1 to the last sampling day. Locations with dashed lines were not fished during that time period.

Time Period	Within year Scheffé groupings		
	1989	1990	1991
Net Station - SC01			
1	A,B	A	A
2	B	A	A
3	A	A,B	A
4	B	B	B
Net Station - SC04			
1	B	A	A
2	A,B	A,B	A
3	A	B,C	A
4	B	C	--
Simpson Cove			
1	B	A	A
2	B	A,B	A
3	A	B	A
4	B	C	A

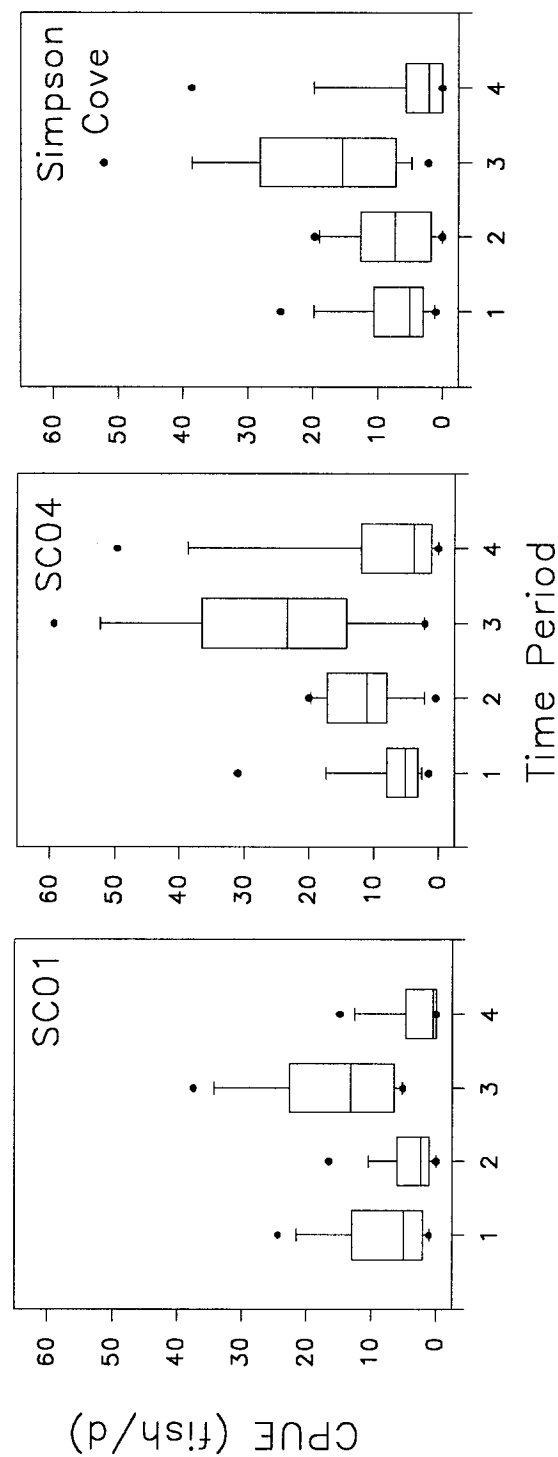


FIGURE 3.29.- Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco > 200 mm FL in Simpson Cove in 1989. 1 = the first sampling day to July 31; 2 = August 1 to 14; 3 = August 15 to 31; 4 = September 1 to the last sampling day.

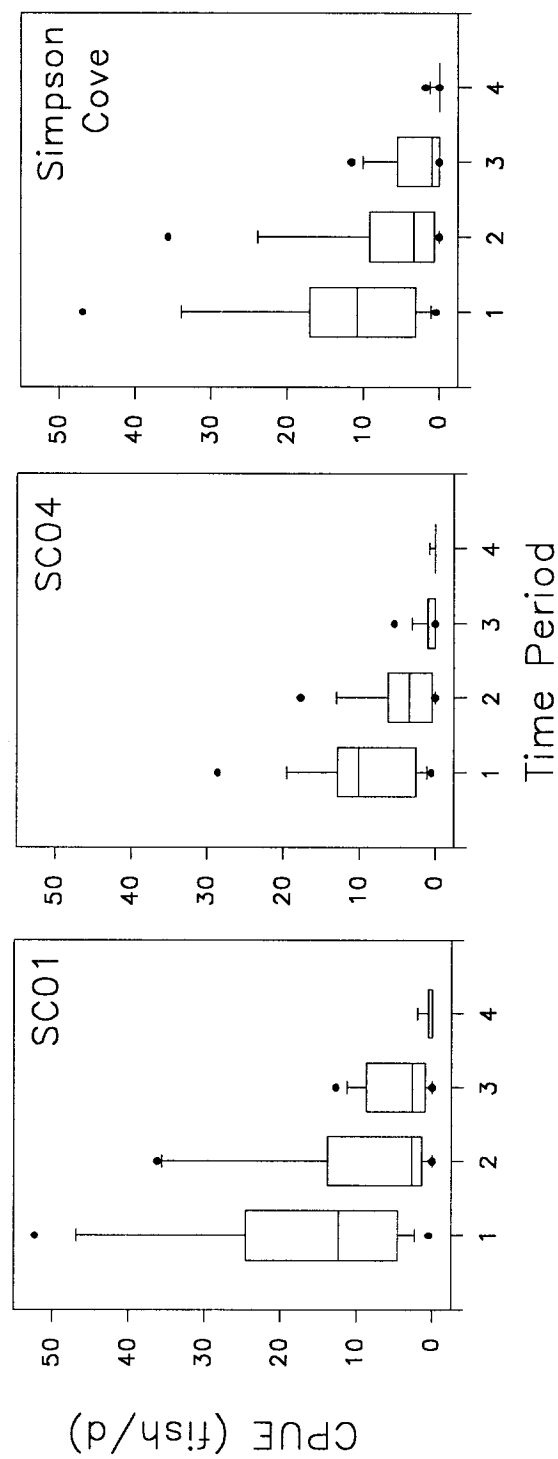


FIGURE 3.30.— Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco > 200 mm FL in Simpson Cove 1990. 1 = the first sampling day to July 31; 2 = August 1 to 14; 3 = August 15 to 31; 4 = September 1 to the last sampling day.

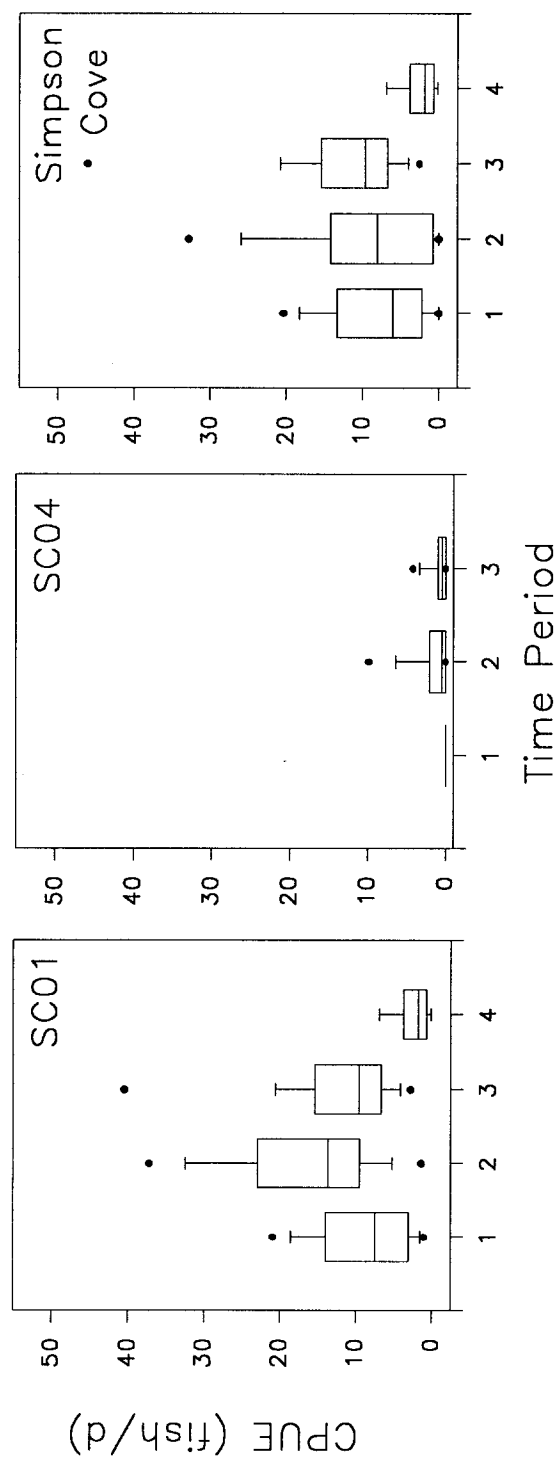


FIGURE 3.31.— Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco > 200 mm FL in Simpson Cove in 1991. 1 = the first sampling day to July 31; 2 = August 1 to 14; 3 = August 15 to 31; 4 = September 1 to the last sampling day.

TABLE 3.17.— Comparison of daily CPUE (fish/d) observations among time periods for Arctic cisco > 200 mm FL in Kaktovik Lagoon, 1989-91. For each net station/sampling area those time periods with the same letter, within each year, are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons). Time period 1 corresponds to the period from the first sampling day to July 31. Time period 2 corresponds to the period from August 1 to August 14. Time period 3 corresponds to the period from August 15 to August 31. Time period 4 corresponds to the period from September 1 to the last sampling day.

Time Period	Within year Scheffé groupings		
	1989	1990	1991
Net Station - KL05			
1	A	A,B	A
2	A,B	A	A
3	A,B	B,C	A
4	B	C	A
Net Station - KL10			
1	A,B	A	A
2	B	A	A
3	A	A	A
4	A,B	A	A
Kaktovik Lagoon			
1	A	A	B
2	A	A	A
3	A	A,B	A,B
4	A	B	A,B

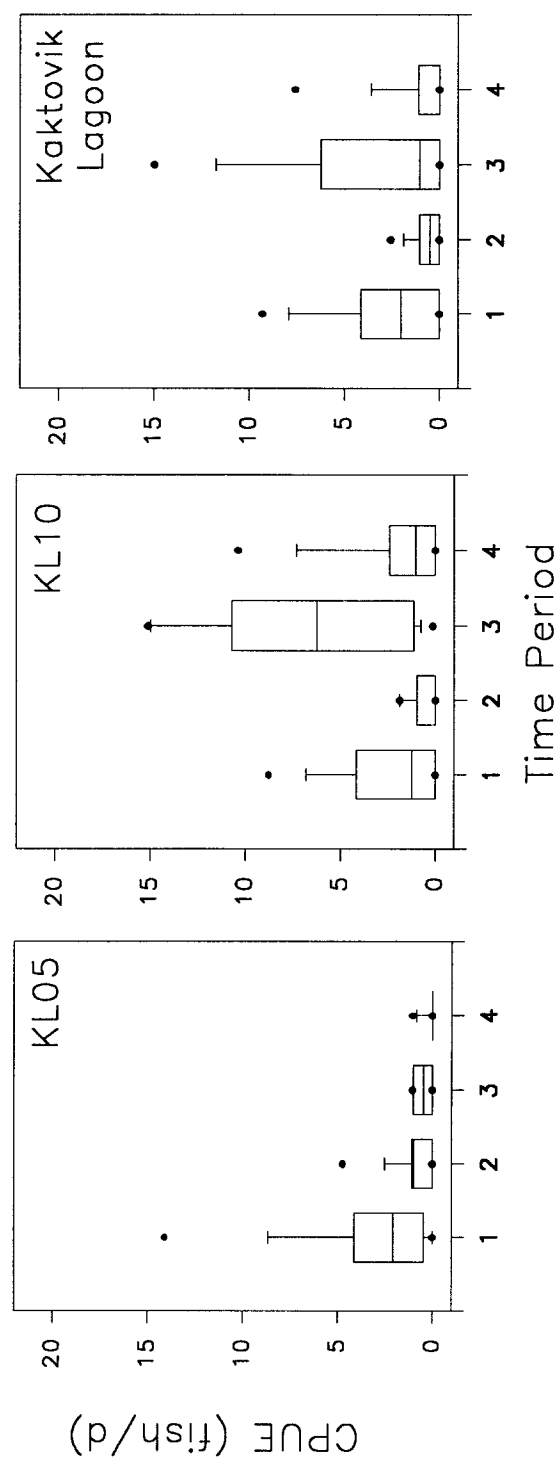


FIGURE 3.32.- Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco > 200 mm FL in Kaktovik Lagoon in 1989. 1 = the first sampling day to July 31; 2 = August 1 to 14; 3 = August 15 to 31; 4 = September 1 to the last sampling day.

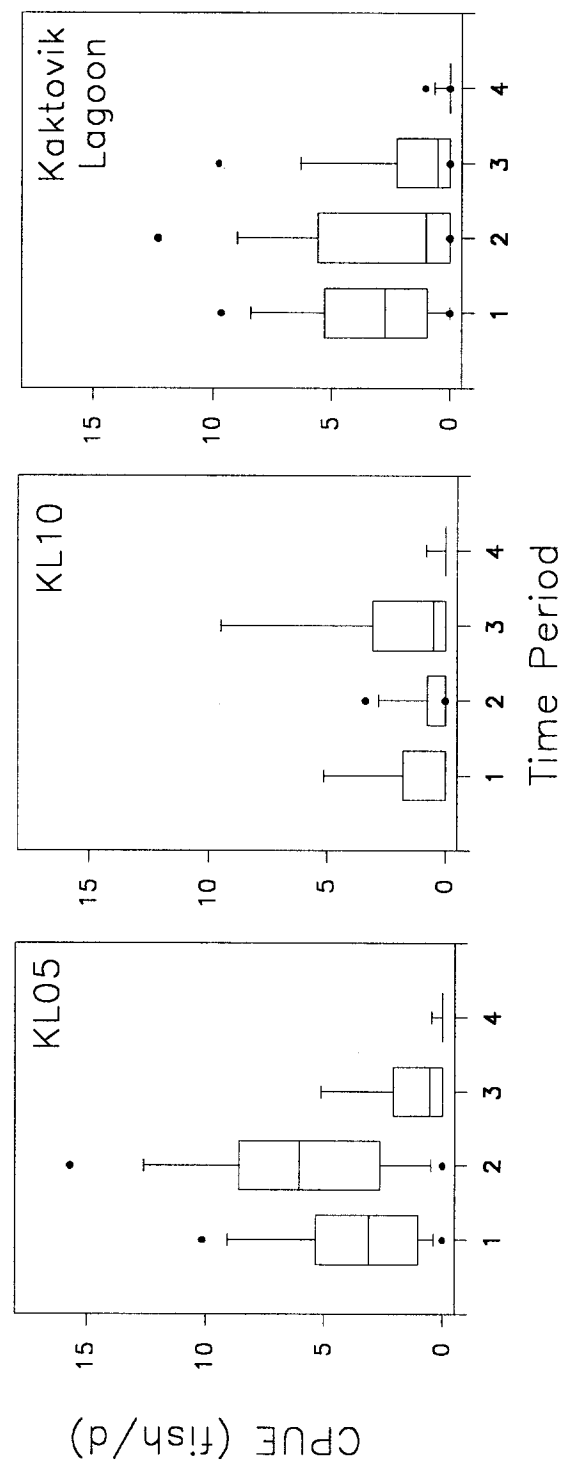


FIGURE 3.33.— Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco > 200 mm FL in Kaktovik Lagoon in 1990. 1 = the first sampling day to July 31; 2 = August 1 to 14; 3 = August 15 to 31; 4 = September 1 to the last sampling day.

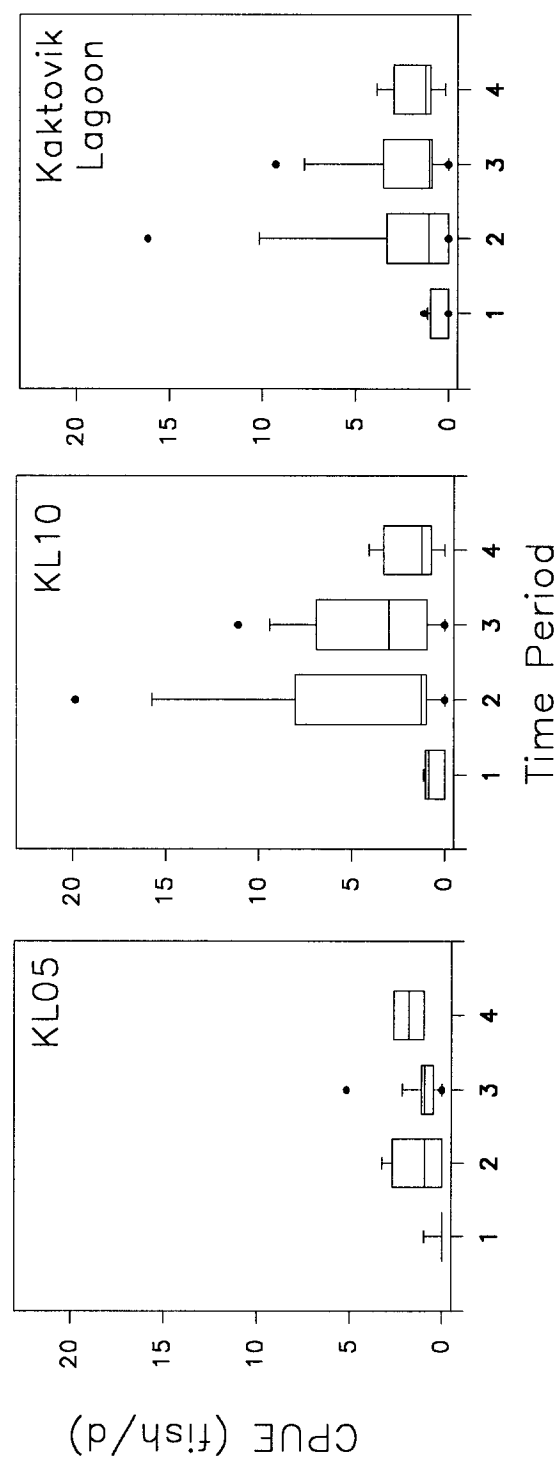


FIGURE 3.34.— Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco > 200 mm FL in Kaktovik Lagoon in 1991. 1 = the first sampling day to July 31; 2 = August 1 to August 14; 3 = August 15 to 31; 4 = September 1 to the last sampling day.

TABLE 3.18.— Comparison of daily CPUE (fish/d) observations among time periods for Arctic cisco > 200 mm FL in Jago Lagoon, 1989-91. For each net station/sampling area those time periods with the same letter, within each year, are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons). Time period 1 corresponds to the period from the first sampling day to July 31. Time period 2 corresponds to the period from August 1 to August 14. Time period 3 corresponds to the period from August 15 to August 31. Time period 4 corresponds to the period from September 1 to the last sampling day.

Time Period	Within year Scheffé groupings		
	1989	1990	1991
Net Station - JL12			
1	B	A	A
2	B	A	A
3	A	A	A
4	B	A	A
Net Station - JL14			
1	A	A,B	A
2	B	A	A
3	A	A,B	A
4	B	B	A
Jago Lagoon			
1	A	A,B	A
2	B	A	A
3	A	A,B	A
4	B	B	A

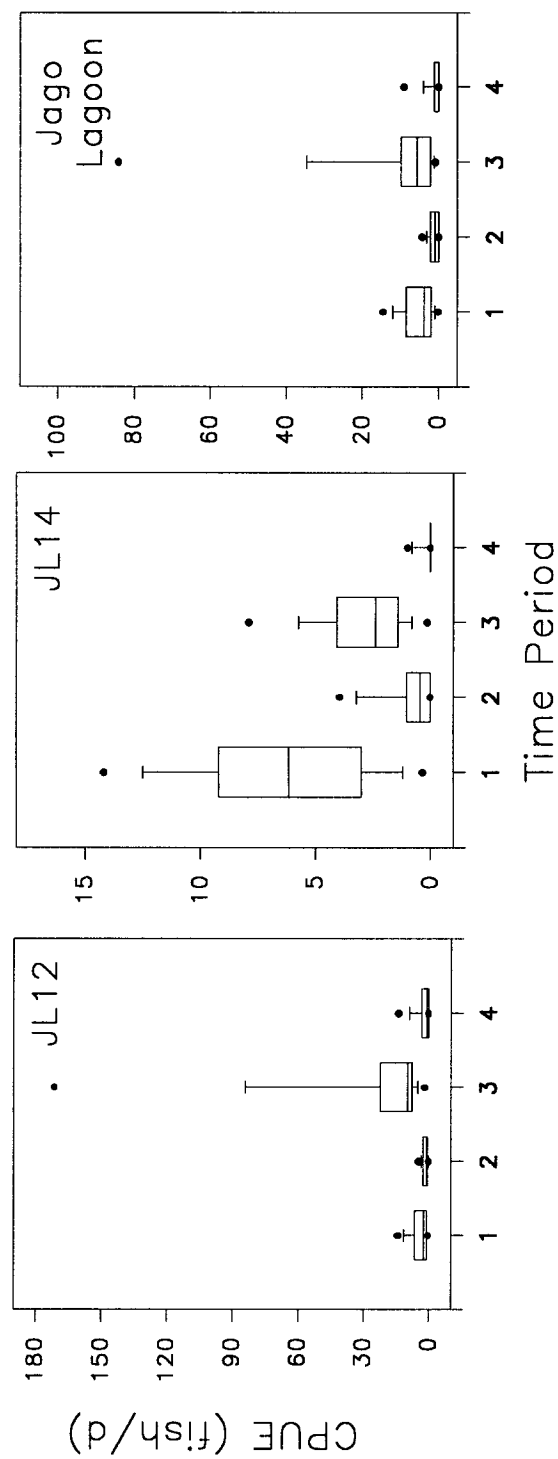


FIGURE 3.35.— Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco > 200 mm FL in Jago Lagoon in 1989. 1 = the first sampling day to July 31; 2 = August 1 to 14; 3 = August 15 to 31; 4 = September 1 to the last sampling day.

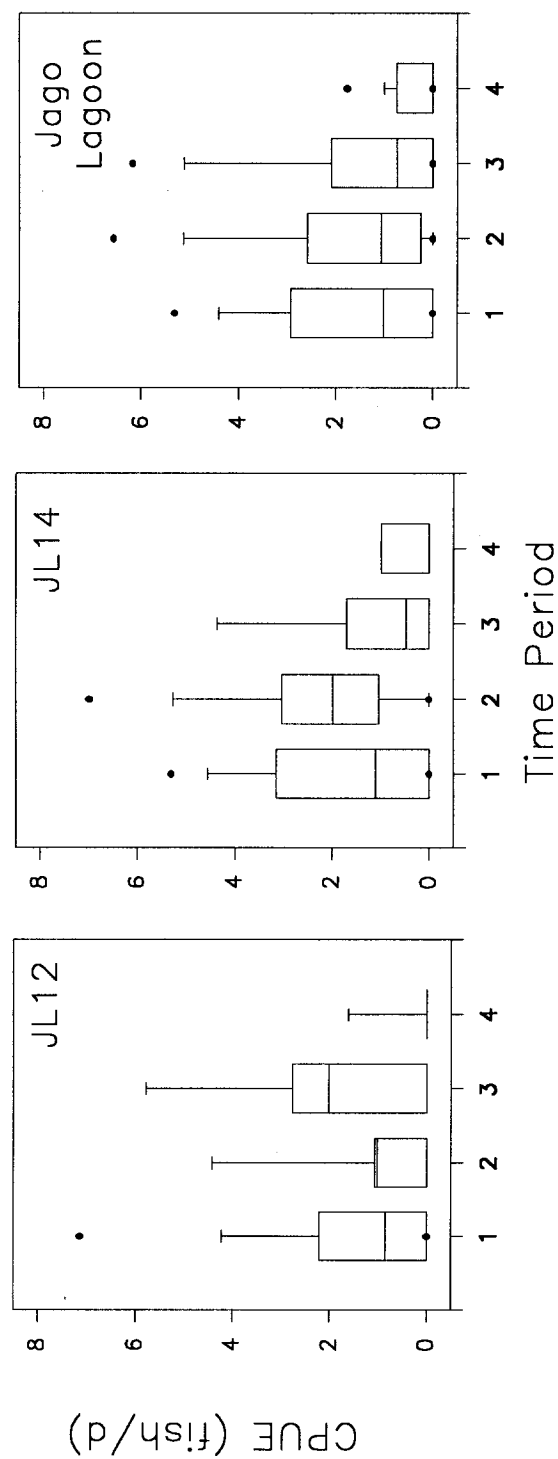


FIGURE 3.36.— Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco > 200 mm FL in Jago Lagoon in 1990. 1 = the first sampling day to July 31; 2 = August 1 to 14; 3 = August 15 to 31; 4 = September 1 to the last sampling day.

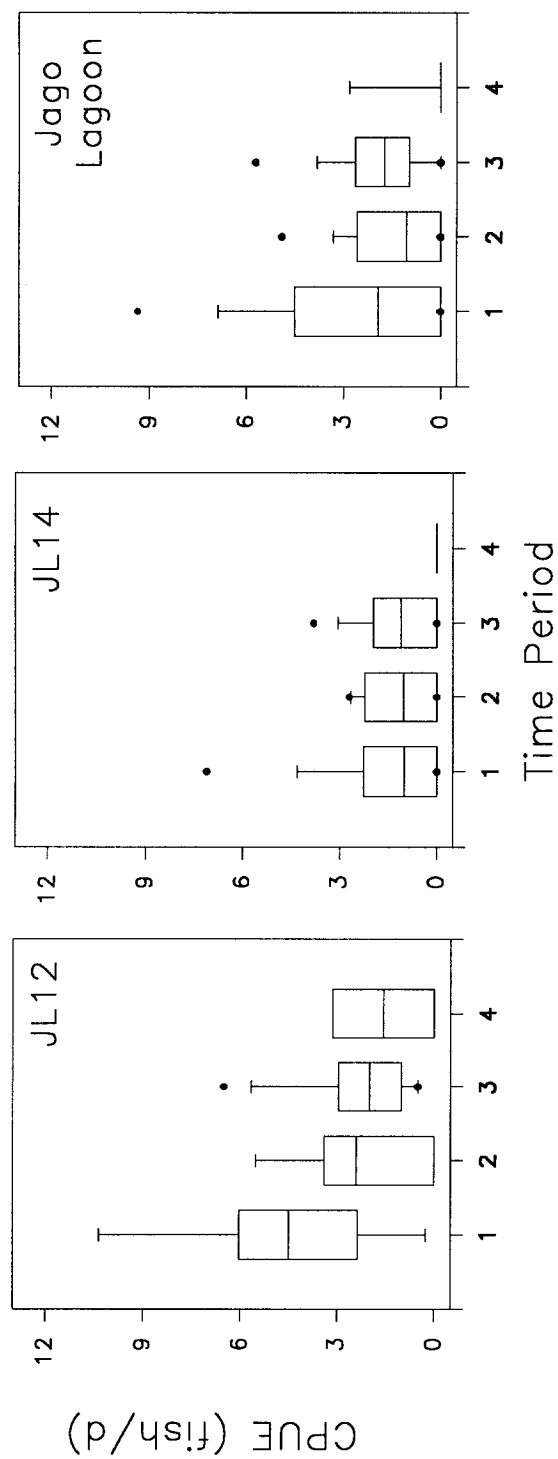


FIGURE 3.37.- Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco > 200 mm FL in Jago Lagoon in 1991. 1 = the first sampling day to July 31; 2 = August 1 to 14; 3 = August 15 to 31; 4 = September 1 to the last sampling day.

During 1990 daily catch rates of large Arctic cisco at net stations BL02 and BL04 and in the Beaufort Lagoon sampling area were generally highest at the beginning of sampling (Table 3.19; Figure 3.38). Daily catch rates were stable for these Beaufort Lagoon locations during the 1991 sampling season (Table 3.19; Figure 3.39).

Among-year comparisons indicate that daily catch rates of large Arctic cisco did not differ among years at net station SC01 (Table 3.20; Figure 3.40). Daily catch rates of large Arctic cisco at net station SC04 were highest in 1989, intermediate in 1990, and lowest during 1991. In 1989 daily catch rates in Simpson Cove were the highest of the years analyzed. Daily catch rates did not differ between 1990 and 1991.

At net station KL05 daily catch rates differed only between 1990 and 1989, with those in 1990 being higher (Table 3.20; Figure 3.41). Daily catch rates did not differ between 1989 and 1991, which were both greater than those observed during 1990. Kaktovik Lagoon daily catch rates did not differ among years.

Daily catch rates of large Arctic cisco at net station JL12 did not differ between 1989 and 1991, and were lowest during 1990 (Table 3.20; Figure 3.42). At net station JL14 daily catch rates did not differ between years. In the Jago Lagoon sampling area only 1989 and 1990 daily catch rates differed, with those observed during 1989 being higher.

At net stations BL02 and BL04 and in the Beaufort Lagoon sampling area daily catch rates were lower during 1990 than those observed during 1991 (Table 3.20; Figure 3.43).

Within a time period, among-year comparisons indicated that daily catch rates of large Arctic cisco did not have consistent discernible patterns at Simpson Cove, Kaktovik or Jago lagoons' locations (Tables 3.21-3.23; Figures 3.44-3.49). This lack of reoccurring trends makes interpretation of results difficult.

In contrast, Beaufort Lagoon locations had patterns which are similar to those described for the analyses with time periods pooled. Daily catch rates during all time periods at net stations BL02 and after August 1 at net station BL04 and in the Beaufort Lagoon sampling area were higher in 1991 than in 1990 (Table 3.24; Figures 3.50-3.51). During July at net station BL04 and in the Beaufort Lagoon sampling area daily catch rates did not differ between years.

Length Frequency Distributions

Arctic cisco ranged from 21 to 566 mm FL during 1988-91. Length frequency distributions generally indicated bimodal patterns for the stratifications by time period, year, and area (Figures 3.52-3.60). Except for a few cases, strong modes appeared between 100 and 200 mm FL and at lengths between 300 and 500 mm. Throughout the distributions, there was an obvious lack of fish at lengths 200-300 mm.

In Simpson Cove very small fish, < 100 mm FL, occurred in the beginning of

TABLE 3.19.- Comparison of daily CPUE (fish/d) observations among time periods for Arctic cisco > 200 mm FL in Beaufort Lagoon, 1990 and 1991. For each net station/sampling area those time periods with the same letter, within each year, are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons). Time period 1 corresponds to the period from the first sampling day to July 31. Time period 2 corresponds to the period from August 1 to August 14. Time period 3 corresponds to the period from August 15 to August 31. Time period 4 corresponds to the period from September 1 to the last sampling day.

Time Period	Within year Scheffé groupings	
	1990	1991
Net Station - BL02		
1	A	A
2	B	A
3	B	A
4	B	A
Net Station - BL04		
1	A	A
2	B	A
3	A,B	A
4	B	A
Beaufort Lagoon		
1	A	A
2	B	A
3	B	A
4	B	A

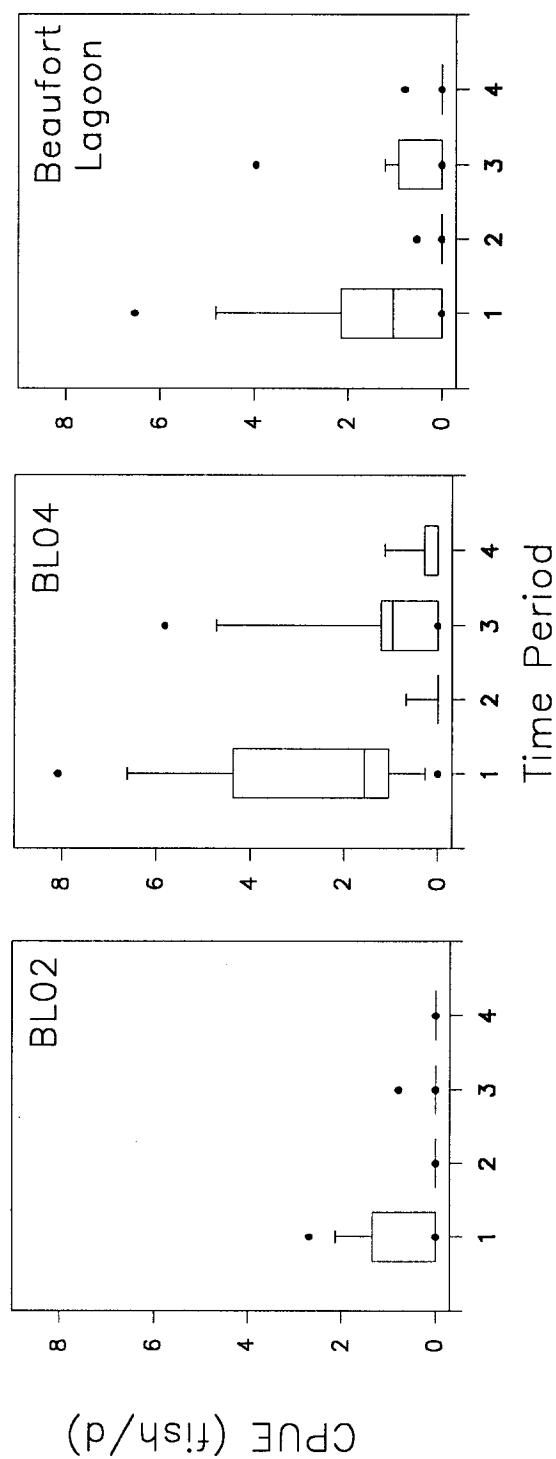


FIGURE 3.38.— Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco > 200 mm FL in Beaufort Lagoon in 1990. 1 = the first sampling day to July 31; 2 = August 1 to 14; 3 = August 15 to 31; 4 = September 1 to the last sampling day.

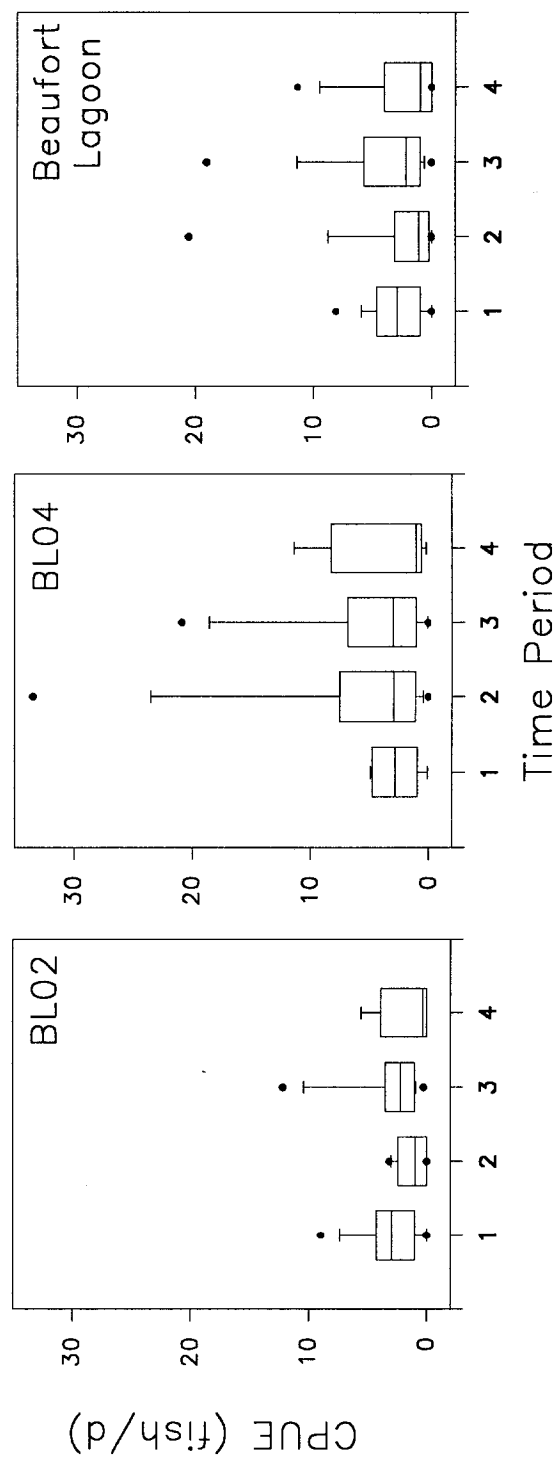


FIGURE 3.39.- Boxplots comparing daily CPUE (fish/d) observations among time periods for Arctic cisco > 200 mm FL in Beaufort Lagoon in 1991. 1 = the first sampling day to July 31; 2 = August 1 to 14; 3 = August 15 to 31; 4 = September 1 to the last sampling day.

TABLE 3.20.— Comparison of daily CPUE (fish/d) observations among years for Arctic cisco > 200 mm FL. For each net station/sampling area those years with the same letter are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons).

Year	Within location Scheffé groupings		
	Net Station	Net Station	Sampling Area
	SC01	SC04	Simpson Cove
1989	A	A	A
1990	A	B	B
1991	A	C	B
	KL05	KL10	Kaktovik Lagoon
1989	B	A	A
1990	A	B	A
1991	A,B	A	A
	JL12	JL14	Jago Lagoon
1989	A	A	A
1990	B	A	B
1991	A	A	A,B
	BL02	BL04	Beaufort Lagoon
1990	B	B	B
1991	A	A	A

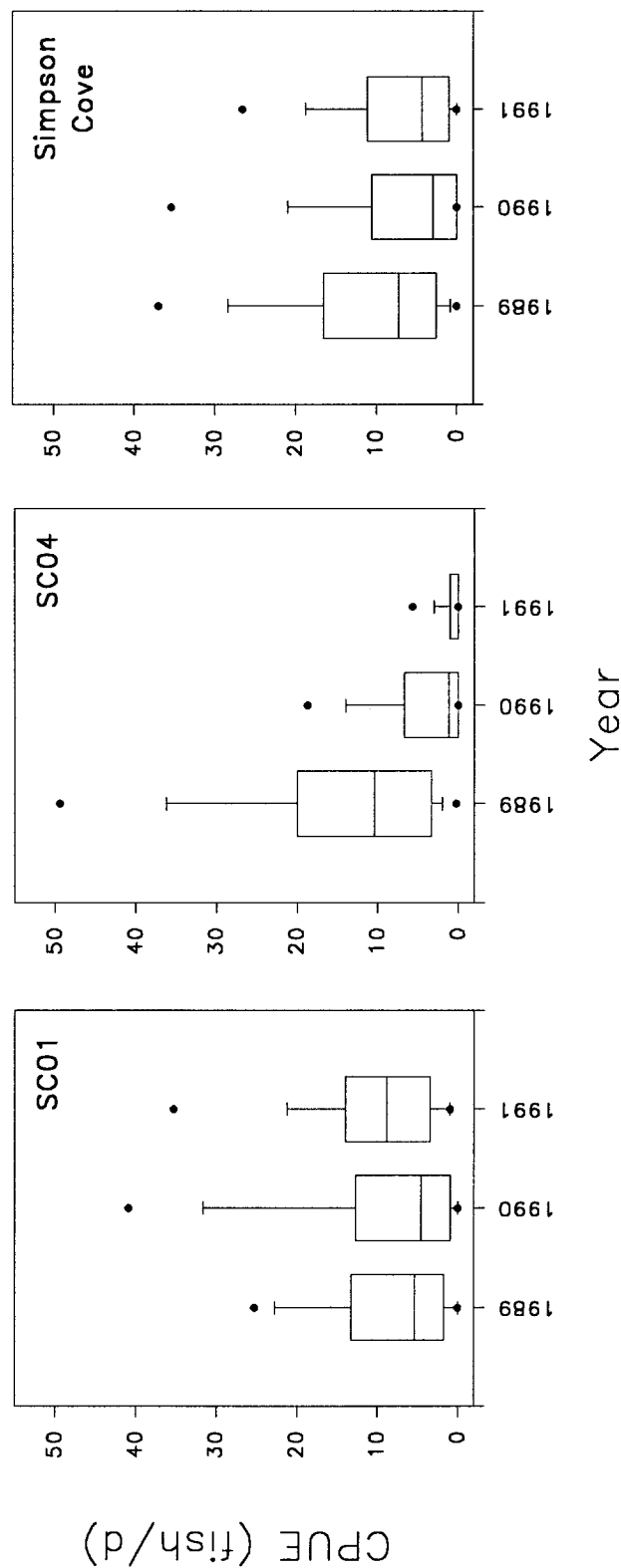


FIGURE 3.40.— Boxplots comparing daily CPUE (fish/d) observations among years for Arctic cisco > 200 mm FL in Simpson Cove.

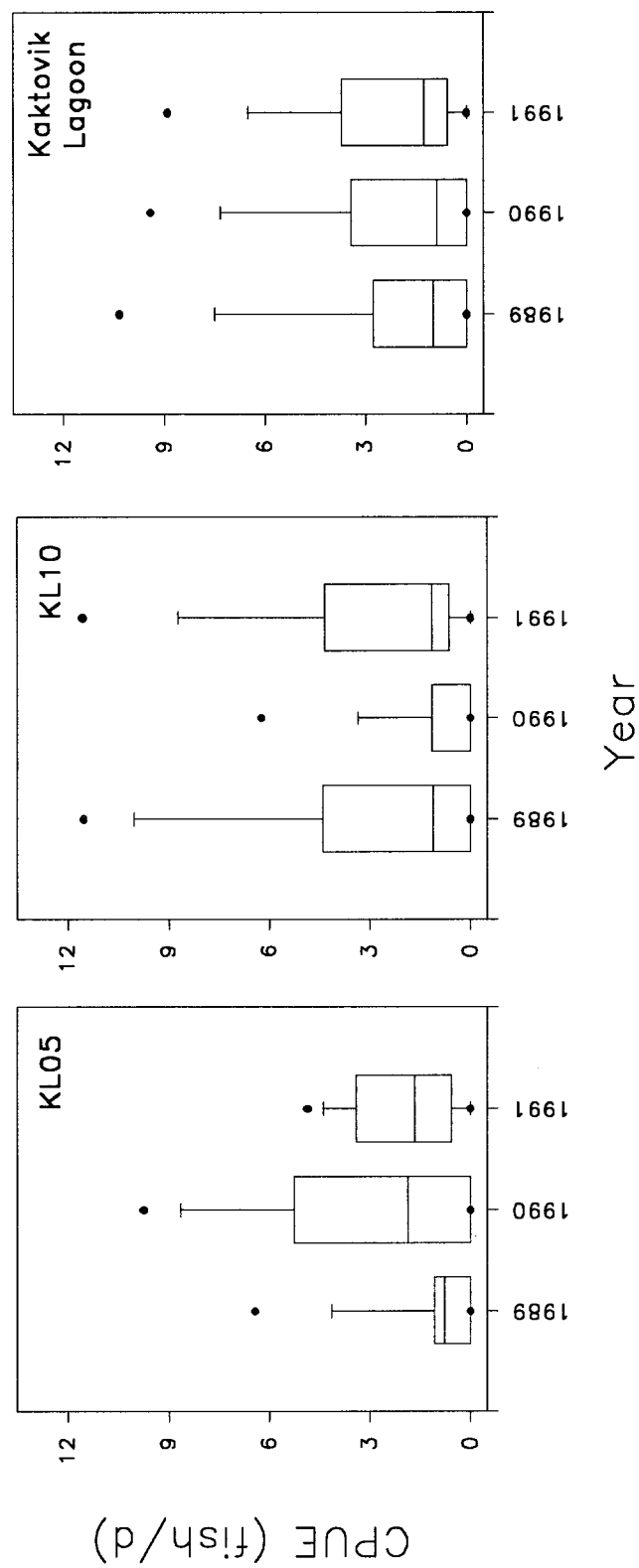


FIGURE 3.41.- Boxplots comparing daily CPUE (fish/d) observations among years for Arctic cisco ≤ 200 mm FL in Kaktovik Lagoon.

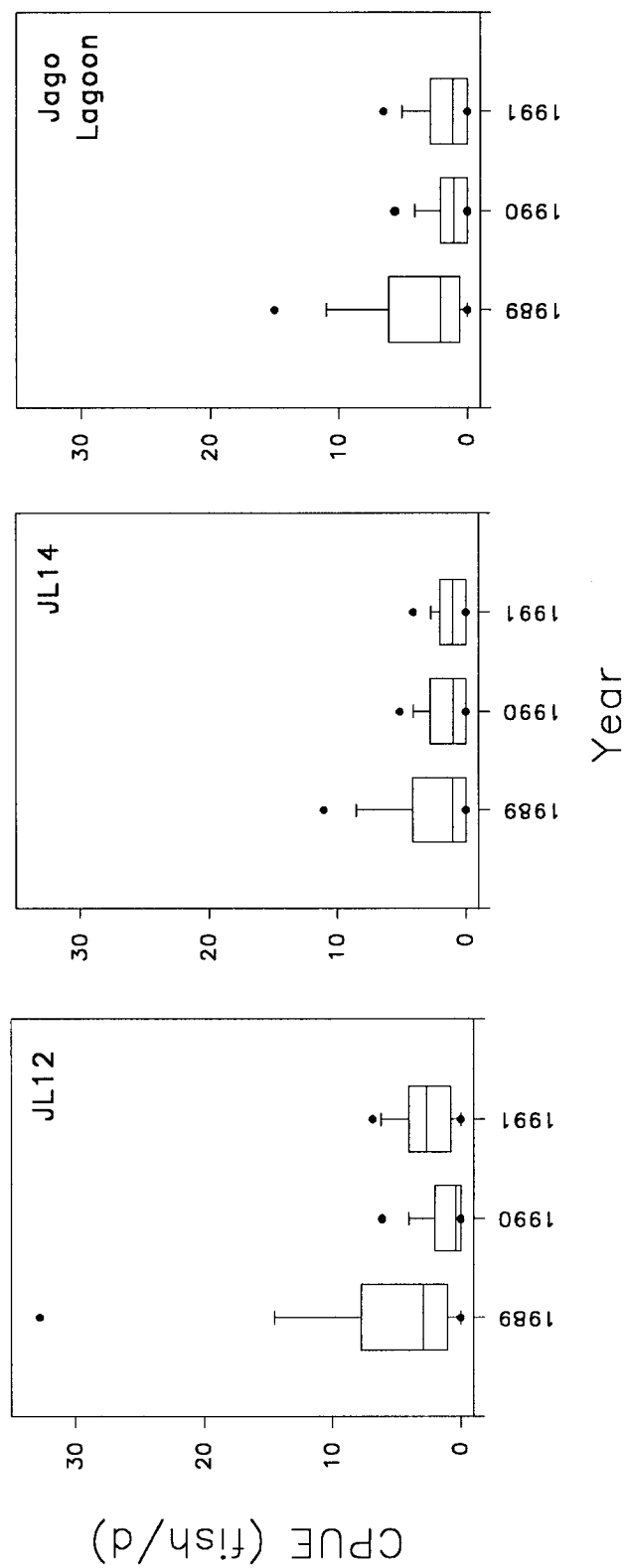


FIGURE 3.42.- Boxplots comparing daily CPUE (fish/d) observations among years for Arctic cisco > 200 mm FL in Jago Lagoon.

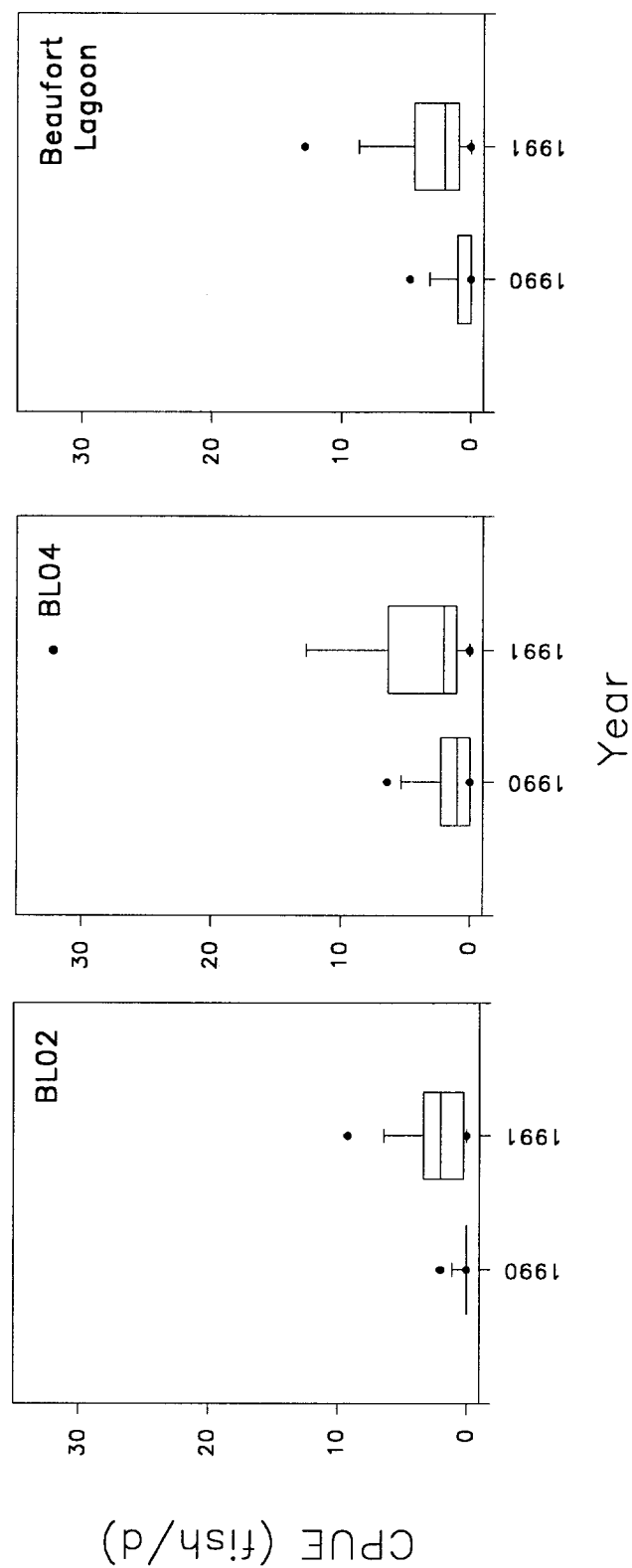


FIGURE 3.43.— Boxplots comparing daily CPUE (fish/d) observations between years for Arctic cisco > 200 mm FL in Beaufort Lagoon.

TABLE 3.21.- Comparison of daily CPUE (fish/d) observations among years for Arctic cisco > 200 mm FL in Simpson Cove. For each net station/sampling area those years with the same letter, within the time period, are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons). Locations with dashed lines were not sampled during that year.

Within location Scheffé groupings			
Year	SC01	SC04	Simpson Cove
Time Period 1 - first day to July 31			
1989	A	A	A
1990	A	A	A
1991	A	B	A
Time Period 2 - August 1 to August 14			
1989	B	A	A
1990	A,B	B	A
1991	A	B	A
Time Period 3 - August 15 to August 31			
1989	A	A	A
1990	B	B	B
1991	A	B	B
Time Period 4 - September 1 to last day			
1989	A	A	A
1990	A	B	B
1991	A	--	A

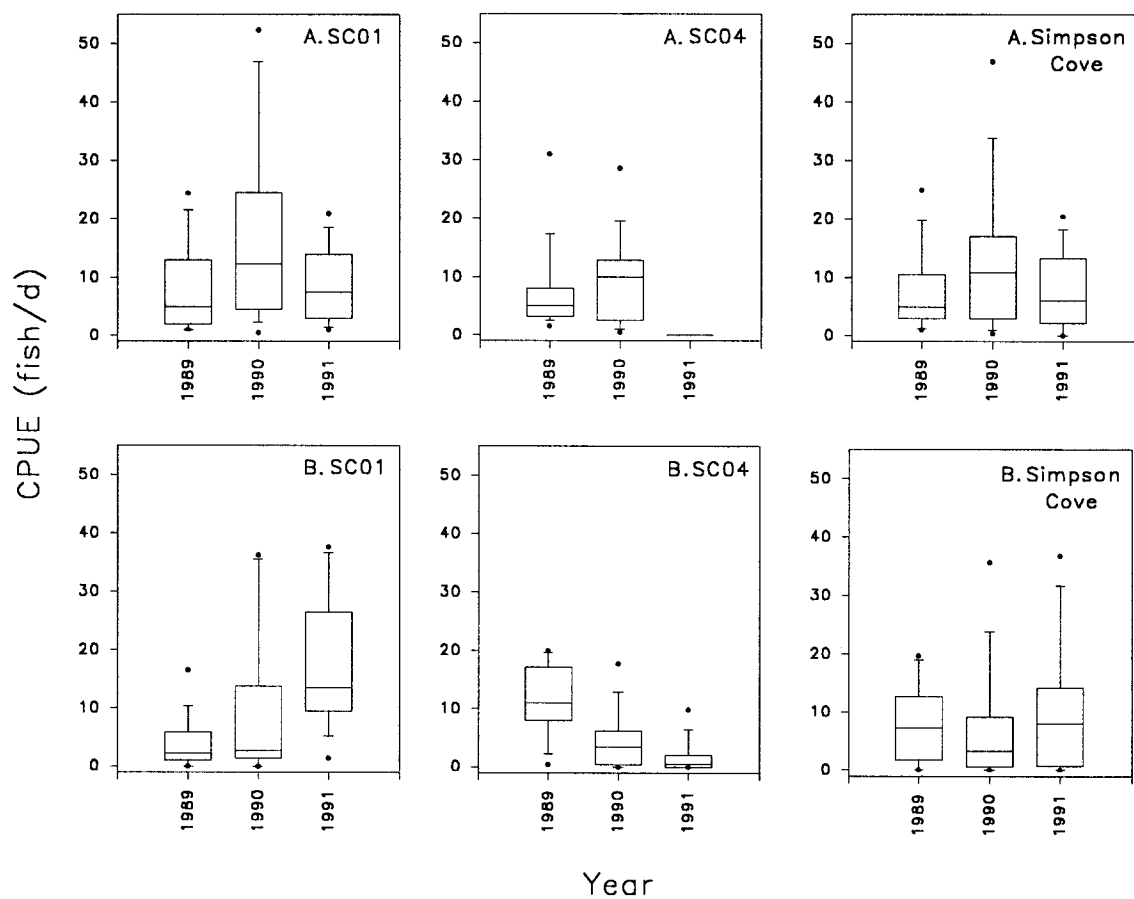


FIGURE 3.44.— Boxplots comparing daily CPUE (fish/d) observations among years for Arctic cisco > 200 mm FL in Simpson Cove. A = time period 1, the first sampling day to July 31. B = time period 2, August 1 to August 14.

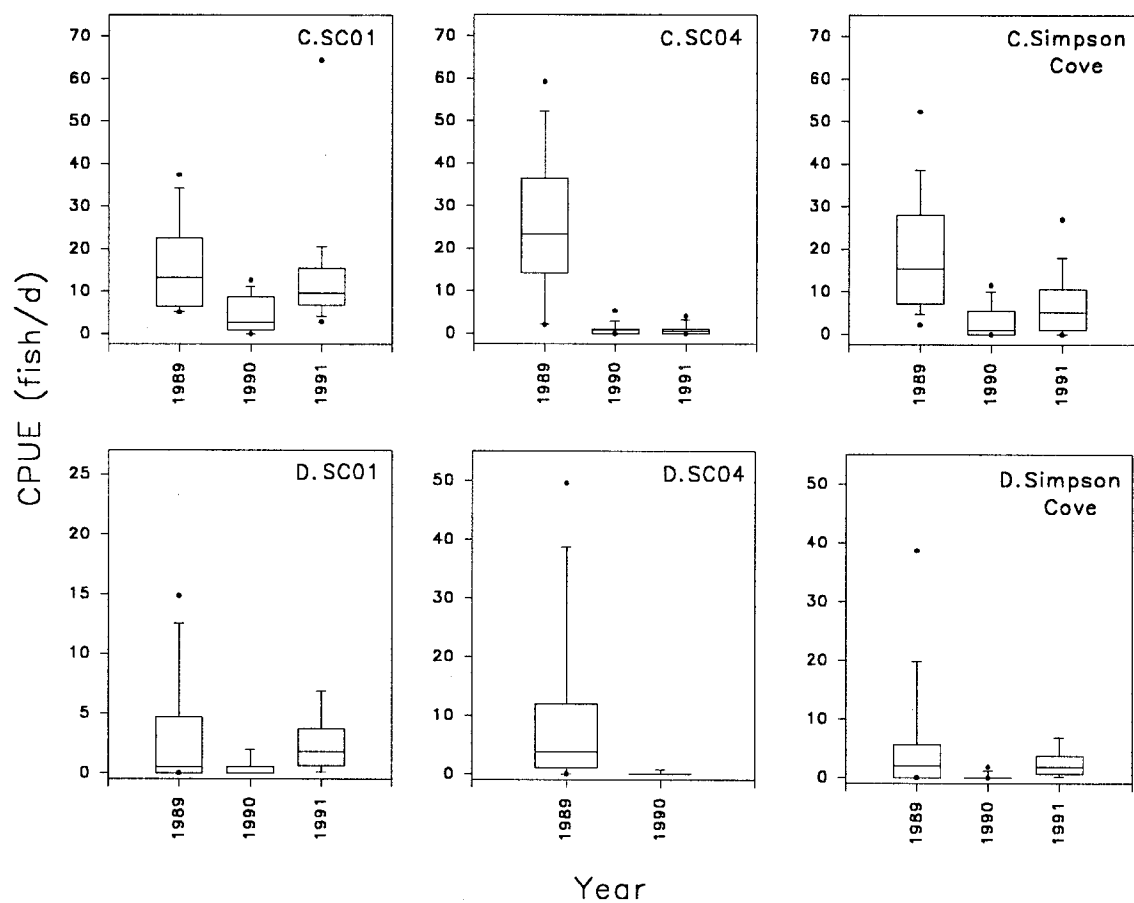


FIGURE 3.45.— Boxplots comparing daily CPUE (fish/d) observations among years for Arctic cisco > 200 mm FL in Simpson Cove. C = time period 3, August 15 to August 31. D = time period 4, September 1 to the last sampling day.

TABLE 3.22.— Comparison of daily CPUE (fish/d) observations among years for Arctic cisco > 200 mm FL in Kaktovik Lagoon. For each net station/sampling area those years with the same letter, within the time period, are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons).

Within location Scheffé groupings			
Year	KL05	KL10	Kaktovik Lagoon
Time Period 1 - first day to July 31			
1989	A,B	A	A
1990	A	A	A
1991	B	A	B
Time Period 2 - August 1 to August 14			
1989	B	B	B
1990	A	B	A,B
1991	A,B	A	A
Time Period 3 - August 15 to August 31			
1989	B	A	A
1990	A,B	B	A
1991	A	A,B	A
Time Period 4 - September 1 to last day			
1989	A	A,B	A,B
1990	A	B	B
1991	A	A	A

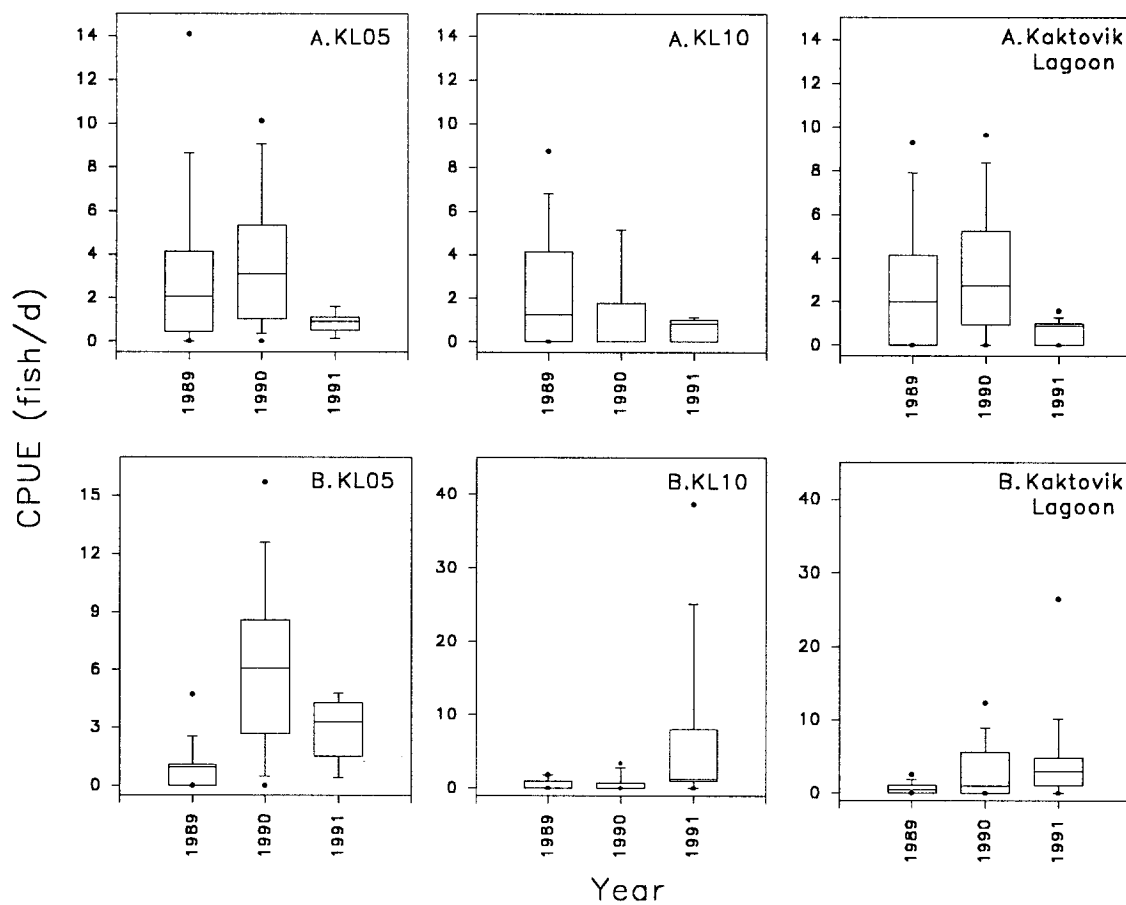


FIGURE 3.46.— Boxplots comparing daily CPUE (fish/d) observations among years for Arctic cisco > 200 mm FL in Kaktovik Lagoon. A = time period 1, the first sampling day to July 31. B = time period 2, August 1 to August 14.

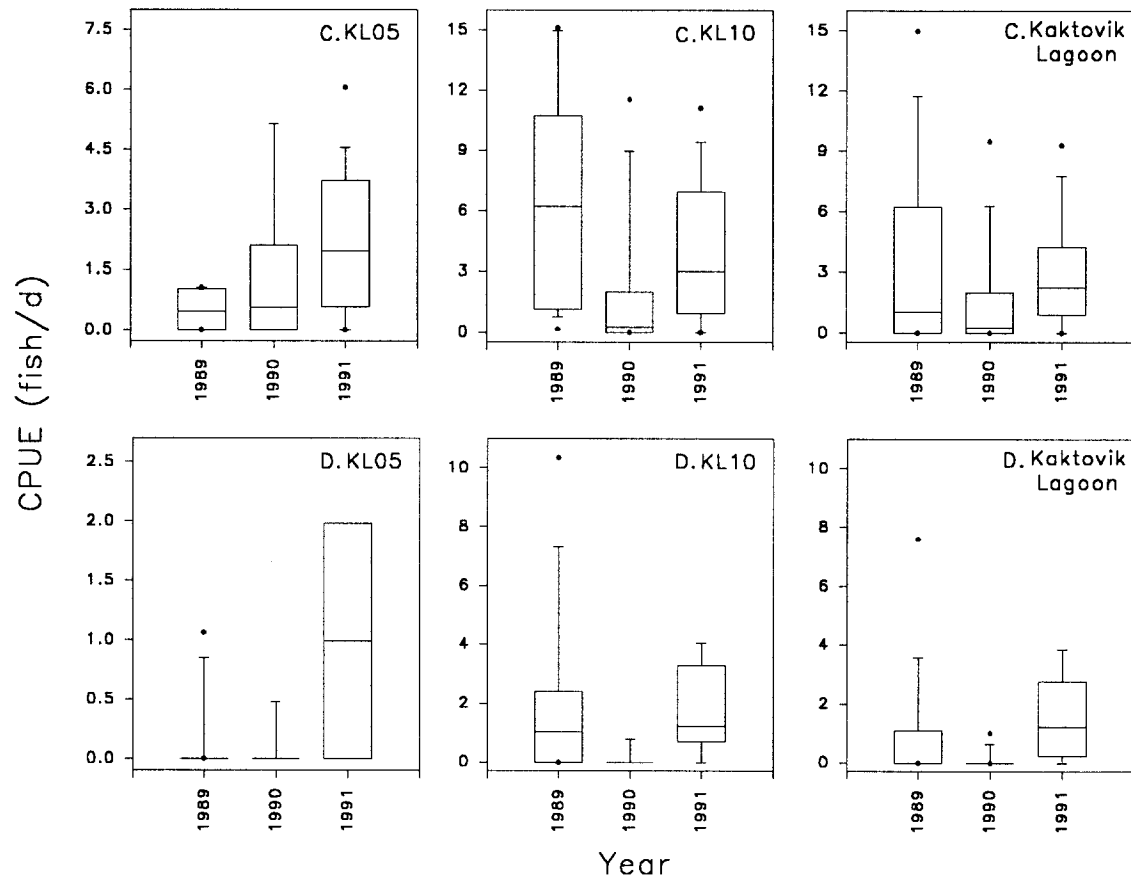


FIGURE 3.47.— Boxplots comparing daily CPUE (fish/d) observations among years for Arctic cisco > 200 mm FL in Kaktovik Lagoon. C = time period 3, August 15 to August 31. D = time period 4, September 1 to the last sampling day.

TABLE 3.23.- Comparison of daily CPUE (fish/d) observations among years for Arctic cisco > 200 mm FL in Jago Lagoon. For each net station/sampling area those years with the same letter, within the time period, are not significantly different (Kruskal-Wallis test with Scheffé multiple comparisons).

Within location Scheffé groupings			
Year	JL12	JL14	Jago Lagoon
Time Period 1 - first day to July 31			
1989	A	A	A
1990	B	B	B
1991	A	B	B
Time Period 2 - August 1 to August 14			
1989	A	A	A
1990	A	A	A
1991	A	A	A
Time Period 3 - August 15 to August 31			
1989	A	A	A
1990	B	A	B
1991	B	A	B
Time Period 4 - September 1 to last day			
1989	A	A	A
1990	A	A	A
1991	A	A	A